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Bioethicopedagogy of Aging and Nahuatl Philosophy: Toward Teacher Flourishing in Inclusive Intergenerational Education

Trinidad Tolentino Ramírez, Escuela Normal de Ecatepec, Mexico

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Abstract

Within the framework of the Doctorate in Pedagogy at the Escuela Normal de Ecatepec, this study examines the cognitive aging of retired teachers in Latin America, a stage often characterized by social invisibility, loss of recognition, and the absence of educational policies that reframe it as a period of learning and dignity. The problem is approached from a critical philosophical perspective, in which bioethicopedagogy emerges as an innovative category that articulates care for life, knowledge, and lifelong learning. The theoretical framework is transdisciplinary, integrating Potter's bioethics, Freire's critical pedagogy, Nahuatl philosophy, and the figure of the *tlamatini*, understood as a sage and shaper of "faces and hearts." This perspective seeks to recover Mesoamerican philosophical roots—expressed through "flower and song" as symbols of wisdom—in order to contribute to Latin American thought and to rethink teacher aging from an ethical, pedagogical, and civilizational horizon. Methodologically, the study adopts a qualitative, documentary approach through a systematic literature review based on the PRISMA method. Databases such as SciELO, Redalyc, Google Scholar, and institutional repositories were consulted, focusing on recent publications related to aging, teaching, and social well-being. Preliminary findings reveal the predominance of biomedical and functional approaches, along with the absence of intercultural philosophical-pedagogical perspectives. The study concludes that integrating ancestral thought with contemporary frameworks allows for the re-signification of retired teachers as epistemic subjects and agents of social well-being, contributing to the development of a more inclusive, ethical, and humanizing gerontological model.

Keywords: cognitive aging, retired teachers, nahuatl philosophy, bioethicopedagogy

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Introduction

Within the context of contemporary demographic and social transformations, population aging represents one of the most pressing challenges for educational and social systems in Latin America. Among the most invisibilized groups within this phenomenon are retired teachers, who, after decades of educational service, face retirement processes marked by isolation, loss of recognition, and progressive cognitive decline, with limited pedagogical initiatives aimed at reframing this stage as a period of learning, participation, and dignity. In this regard, Huenchuan (2018) highlights the existence of the "Inter-American Convention on the Protection of the Human Rights of Older Persons," which seeks to reaffirm their importance and promote action among stakeholders (p. 88). This underscores the urgency of rethinking the role of older adults—and particularly retired teachers—within public, educational, and cultural policy frameworks.

The scientific literature reviewed between 2013 and 2022 reveals a concerning tendency to reduce cognitive aging to a medical-functional phenomenon, overlooking the symbolic, cultural, and educational dimensions of teacher aging. This limited perspective not only marginalizes the potential of older adults as agents of knowledge but also neglects the need to develop inclusive, ethically grounded, and culturally contextualized educational proposals. Despite international efforts to promote healthy aging (OMS, 2020), there remains a lack of integrative theoretical models that articulate lifelong learning, social well-being, and epistemic justice.

This epistemic and pedagogical gap has motivated the present study, which aims to systematically analyze specialized literature addressing the influence of cognitive aging on the social well-being of retired teachers, in order to identify its dominant interpretive approaches and dimensions. The study adopts a qualitative, transdisciplinary approach, guided by Potter's bioethics (1971), Freire's critical pedagogy (2005), Nussbaum and Sen's (1996) capabilities approach, and Latin American biointerculturality, supported by an analogical hermeneutic analysis that seeks to uncover the deeper meanings embedded in the reviewed discourses and practices.

The structure of this study includes, first, the presentation of the problem statement and theoretical framework; second, the methodological approach; third, the preliminary results; followed by the critical discussion of findings; and finally, the conclusions, which aim to contribute to the development of a bioethicopedagogical model that promotes inclusive intergenerational education and redefines the role of retired teachers as active cognitive citizens.

This study is conceived as an innovative and necessary contribution to rethinking aging within Latin American pedagogy, highlighting the urgency of designing policies and educational practices that embrace diversity, recognize experience, and dignify aging as a formative, critical, and transformative stage of life.

Problem Statement

In recent decades, the aging of the retired teaching population in Latin America has emerged as a significant demographic and social phenomenon. However, its treatment within pedagogy, health, and public policy has been fragmented. Rather than being understood as a fertile stage for the construction of new forms of citizenship, teacher aging has traditionally been interpreted

through deficit-based frameworks that reduce this life stage to processes of physical, cognitive, and functional decline. In this context, the retired teacher appears as an invisibilized social figure, bearer of an active pedagogical memory that is rarely recovered, re-signified, or valued within contemporary educational projects.

Institutional and academic discourses on cognitive aging tend to prioritize biomedical models focused on loss of capacities, reinforcing a pathologizing narrative that overlooks the symbolic, affective, and epistemic contributions of older adults. This one-dimensional perspective obscures biographical learning trajectories and forms of bio-learning that emerge during retirement, where individuals, rather than losing their formative potential, transform their relationship with knowledge, time, and community.

Moreover, retirement—understood merely as the cessation of work—conceals its pedagogical and social dimensions, generating adverse effects on well-being, identity, and active participation among retired teachers. In addition, there is a notable weakness in institutional, familial, and community support networks that could sustain a dignified, participatory, and cognitively active old age. Access to educational, cultural, and mental health services remains conditioned by structural inequalities that reproduce disparities accumulated throughout the life course.

Furthermore, the literature review reveals a limited articulation among bioethical, pedagogical, and cultural approaches necessary to rethink teacher aging from a complex, situated, and critical perspective. Consequently, most studies lack an integrative framework capable of addressing cognitive decline in dialogue with social imaginaries, institutional structures, and contemporary educational narratives.

In response to this scenario, there is a need to develop a bioethicopedagogical model that understands cognitive aging not as a terminal stage of learning, but as a vital phase of re-signification, care, and symbolic production. This integrative model promotes inclusive intergenerational education, recognizing aging as a space of epistemic continuity in which the retired teacher can exercise active cognitive citizenship, contributing to social cohesion and the dialogue of knowledge across generations.

Accordingly, this study aims to systematically analyze the specialized literature addressing the relationship between cognitive aging and social well-being in retired teachers, with the purpose of identifying dominant interpretive approaches, constructed representations of this life stage, and the pedagogical responses—or lack thereof—that shape its position within the Latin American educational landscape.

Research Question

How is the influence of cognitive aging on the social well-being of retired teachers understood in specialized literature?

General Objective

To systematically analyze the specialized literature addressing the influence of cognitive aging on the social well-being of retired teachers in order to identify its main interpretive approaches and dimensions.

Theoretical Framework

The study of cognitive aging in retired teachers, from a transdisciplinary perspective, requires a deep and critical analysis of traditional paradigms that have reduced this stage of life to a process of functional decline. Within this framework, an interpretive model is proposed based on five key categories: Biopedagogy, Bio-learning, Bioethics, Biointerculturality, and Bioethicopedagogy, as a foundation for a more humanized, active, and inclusive understanding of the retired teacher in the post-labor stage.

In this sense, Biopedagogy, according to Maturana and Varela (1998), implies an understanding of learning processes as vital dynamics that involve both biological and relational dimensions. Therefore, learning does not cease with retirement; rather, it transforms, allowing older adults to reconfigure their cognitive identity and social role. The concept of Bio-learning (Medina, 2017; Parra et al., 2019) is directly linked to this perspective, as it recognizes that aging individuals learn through their biography, affectivity, and environment, projecting new forms of engagement with knowledge beyond formal educational settings.

From an ethical standpoint, Potter's foundational work (1971) redefines bioethics as a "bridge to the future," aimed at ensuring dignity, care, and respect for life in all its forms. Within this framework, an intervention-oriented bioethics is proposed—one that goes beyond normative principles to promote transformative actions in response to the structures of exclusion affecting older adults. This vision aligns with Nussbaum and Sen's (1996) capabilities approach, particularly in emphasizing well-being, agency, and active participation in the design of educational and social policies for aging.

In addition to contributions from bioethics and critical pedagogy, this study incorporates elements of Nahuatl philosophy as an intercultural horizon for rethinking aging from non-Western perspectives. In the Mesoamerican tradition, the figure of the tlamatini represents the sage who guides community life through reflective speech and the formation of "faces and hearts," a concept referring to the integral development of individuals in their ethical, intellectual, and social dimensions.

Within this worldview, old age is not conceived merely as a stage of decline, but as a privileged moment of wisdom and counsel. Elders occupy a central role in the transmission of knowledge and values, contributing to social balance through accumulated life experience. The metaphor of "flower and song" (in xōchitl in cuīcatl) symbolizes the search for truth and the expression of profound knowledge—dimensions cultivated throughout life.

Recovering these elements of Nahuatl thought expands the understanding of teacher aging beyond the clinical and productivist frameworks that dominate Western modernity. From this intercultural perspective, the retired teacher can be interpreted as a bearer of pedagogical wisdom, contributing to the continuity of knowledge and the strengthening of the social fabric.

In this regard, Biointerculturality offers a key perspective from Latin America by recognizing the epistemic and cultural plurality of educational and health processes. As proposed by Albuquerque (2015), it advocates for a situated ethics that respects ancestral knowledge, cultural identities, and collective rights in the care of older adults. In the case of retired teachers, biointerculturality enables a re-signification of their role within the educational community as carriers of pedagogical memory—wise figures who articulate generations through active cognitive citizenship.

For example, in the view of Guerrero et al. (2022), biointerculturality is configured as a transformative educational approach that transcends traditional disciplinary boundaries, proposing a holistic and integrative vision of the school. This approach not only challenges fragmented curricular structures but also promotes meaningful connections between school knowledge and the biological, cultural, social, and environmental realities that shape a given territory.

It is important to note that biointerculturality goes beyond a simple articulation between biology and interculturality. Rather, it constitutes a situated pedagogy that recognizes cultural and ecological diversity as fundamental components of the educational process. In this sense, the school is not conceived as a neutral space, but as a territory of coexistence, harmony, and ethical responsibility toward both the environment and humanity.

From this perspective, biointerculturality not only seeks school peace as a microcosm of social peace but also promotes the formation of globally conscious citizens capable of linking the local with the planetary, the cognitive with the ethical, and the educational with the vital. Within this framework, the subject—including older adults—is reclaimed as an epistemic and ecological agent capable of critically responding to contemporary challenges affecting both biocultural diversity and social justice.

Within this horizon, the bioethicopedagogical dimension becomes evident, emphasizing that the retired teacher can not only re-engage as an intergenerational educator but also act as a key agent in rebuilding an educational fabric grounded in harmonious coexistence, epistemic justice, and environmental responsibility from a situated and plural perspective.

From these foundations emerges the theoretical proposal of bioethicopedagogy, understood as an emergent category that articulates the ethical care of life, the continuity of biographical learning, and the intercultural recognition of the aging subject. Bioethicopedagogy is therefore not only an analytical model but also a critical intervention tool aimed at challenging institutional discourses that obscure the residual or emerging cognitive capacities of retired teachers.

Epistemologically, this proposal is grounded in the sociocritical paradigm, which finds one of its most influential voices in Freire (1997, 2005). Aging, like oppression, must be read through a pedagogy of hope, in which the oppressed—in this case, the retired teacher marginalized by productivist logic—can reclaim their history through processes of conscientization, dialogue, and action. This perspective resonates with the decolonial critiques of Boaventura de Sousa Santos, Aníbal Quijano, and Enrique Dussel, who denounce Western modern epistemology as a system that reproduces hierarchies, exclusions, and silences.

Finally, transdisciplinarity, as proposed by Nicolescu (1996), is not merely an integration of knowledge but a complex logic that enables the crossing of levels of reality, the coexistence of multiple logics, and the overcoming of reductionism. In this sense, the research is constructed as a process that articulates biological, cultural, pedagogical, and ethical dimensions of aging, enabling a holistic and situated understanding of the phenomenon under study.

Methodology

This study is conducted through a systematic literature review, adopting a qualitative and transdisciplinary approach aimed at understanding how cognitive aging is represented and how

it influences the social well-being of retired teachers. The study was conducted through a qualitative systematic literature review based on the PRISMA method, consulting SciELO, Redalyc, Google Scholar, and institutional repositories.

Keywords used in the search included cognitive aging, social well-being, retired teachers, bioethics, and lifelong education. Studies published in Spanish and English between 2013 and 2022 were included, provided they adopted pedagogical, ethical, or sociocultural perspectives. Studies with a purely clinical focus, those lacking educational context, or those centered exclusively on older adults without a teaching background were excluded.

The review process enabled the identification of relevant approaches, discourses, and interpretive dimensions, in alignment with the general objective of the study.

Preliminary Results

During the data collection and organization phase, specialized documents published between 2013 and 2022 were analyzed, sourced from databases such as SciELO, Redalyc, Google Scholar, and institutional repositories. The corpus consisted of scientific articles, institutional reports, book chapters, and postgraduate theses, selected for their relevance to cognitive aging, social well-being, lifelong education, and the role of retired teachers.

The analysis was structured using an operationalization matrix that considered dimensions such as types of cognitive decline, functional, emotional, and social impacts, support networks, access to services, and pedagogical proposals. Data organization through cross-tabulation matrices enabled the identification of patterns and trends within the reviewed literature.

Among the most relevant findings is the limited presence of explicit bioethical or biopedagogical approaches, identified in only 18% of the analyzed sources. This limitation reflects the predominance of clinical or functional frameworks that tend to reduce teacher aging to a process of decline, overlooking its epistemic and symbolic dimensions. In this same vein, there is a near absence of biointercultural perspectives, as well as a lack of philosophical frameworks derived from non-Western traditions, including Nahuatl philosophy, revealing a significant gap in Latin American contexts characterized by cultural diversity.

This absence is particularly significant considering that, within the Nahuatl tradition, knowledge is not understood as functional accumulation but as a living expression of experience, encapsulated in the notion of in xōchitl in cuīcatl (flower and song). From this perspective, aging may be interpreted not as loss but as a process of maturation of knowledge—a dimension not reflected in the analyzed literature.

Additionally, significant gaps were identified in the availability of data related to gender, educational level, and geographical origin, limiting the development of more contextualized and inclusive analyses.

Regarding the dimensions of cognitive decline, the results indicate that 39.5% of the studies report mild decline, 32.5% moderate, 20.9% severe, and 7.1% do not specify the type (Huenchuan, 2018; OMS, 2022). These data were organized using cross-tabulation matrices and processed manually.

In terms of social well-being, the most frequently addressed topics in the literature include institutional and family support networks (65%), access to services (58%), and social participation (48%), while specific pedagogical proposals account for only 24% of the total (Giraldo, 2006; López et al., 2019), confirming the limited consideration of retired teachers as active educational agents.

Overall, these findings reveal a dominant tendency toward reductionist approaches and highlight the need for more comprehensive interpretive frameworks. In this regard, the incorporation of analogical hermeneutics, in dialogue with intercultural perspectives such as Nahuatl philosophy, emerges as a relevant pathway for deepening the critical understanding of teacher aging, guiding its re-signification as a formative, socially meaningful, and culturally situated process.

Discussion of Results

The findings indicate that most of the studies reviewed approach the cognitive aging of retired teachers from a predominantly medical or functional perspective, confirming the trend identified in the preliminary analysis. This orientation limits the understanding of the phenomenon by focusing on the decline of capacities, while overlooking its pedagogical, symbolic, and social potential. Consistent with López et al. (2019) and Medina (2017), few studies incorporate bioethical or biopedagogical frameworks, and almost none include a biointercultural perspective, revealing a reductionist view of teacher aging.

In line with these findings, there is also a notable absence of interpretive frameworks derived from non-Western traditions, including Nahuatl philosophy, which is particularly significant in Latin American contexts. This omission restricts the possibility of understanding aging from an intercultural perspective, in which knowledge is not reduced to its functional dimension but is conceived as a living experience and a process of knowledge maturation. In this sense, the exclusion of these perspectives reinforces the hegemony of an epistemological paradigm that obscures alternative ways of understanding knowledge in old age.

In contrast, this study adopts a critical stance grounded in Potter's bioethics (1971), Freire's liberatory pedagogy (2005), and Nussbaum and Sen's (1996) capabilities approach, particularly regarding the rights to imagination, participation, affiliation, and control over one's environment. However, these capabilities are constrained in the reviewed literature, which fails to recognize retired teachers as active epistemic subjects, thereby reinforcing their invisibility within educational and social fields.

Furthermore, the documentary analysis reveals a significant lack of disaggregated data by sex, as well as the invisibilization of the specific trajectories of older women teachers. This omission is especially relevant given that, as noted by López et al. (2019), mistreatment of older adults is more pronounced among women, who often face reduced access to support networks and health services, as well as persistent stereotypes that portray them as passive or dependent.

This lack of a gender perspective constitutes an ethical and methodological gap that limits a comprehensive understanding of social well-being in retirement. Consequently, it is essential for future research to incorporate an intersectional approach that makes visible the structural inequalities shaping the experience of teacher aging and informs the design of more equitable pedagogical and social strategies.

Among the main limitations of this study are the scarcity of research adopting alternative approaches and the lack of comprehensive data on key variables such as gender, geographical context, and professional trajectory, which restricts the potential for more robust and contextualized comparative analyses.

Finally, the findings underscore the need to advance toward transdisciplinary theoretical frameworks and participatory methodologies that recover the voices of retired teachers themselves. In this regard, the integration of bioethical, biopedagogical, and intercultural perspectives—including dialogue with philosophical traditions such as Nahuatl thought—emerges as a fundamental pathway for re-signifying teacher aging as an active, critical, and socially engaged stage of life.

Conclusion

The systematic review demonstrates that research on cognitive aging in retired teachers is predominantly shaped by biomedical or functional approaches. While these perspectives have contributed to clinical knowledge, they have relegated pedagogical, cultural, and symbolic dimensions, reinforcing a reductionist view that obscures retired teachers as active epistemic subjects.

The findings reveal a lack of integrative interpretive frameworks that articulate human dignity, cultural diversity, and the continuity of learning, as well as a limited presence of bioethical, biopedagogical, and intercultural approaches—including the omission of traditions such as Nahuatl philosophy—highlighting the need for transdisciplinary perspectives.

Furthermore, the absence of disaggregated data by gender, region, and professional trajectory constrains more accurate diagnoses and the design of inclusive policies, underscoring the urgency of incorporating intersectional approaches.

In response to these gaps, this study proposes the bioethicopedagogical model as a theoretical and methodological framework that re-signifies retired teachers as active cognitive citizens, capable of strengthening intergenerational dialogue and contributing to more just educational communities. However, the scarcity of alternative studies and systematic data points to the need for empirical and participatory research.

Within this framework, it is recommended to promote research lines and educational programs that integrate retired teachers into processes of learning and knowledge production.

From a Nahuatl philosophical perspective, old age does not represent the end of knowledge but its maturation. The tlamatini, as a shaper of “faces and hearts,” embodies a living memory that continues to flourish. Recognizing this wisdom constitutes an act of epistemic justice and a necessary condition for building more humane and intergenerational societies.

In sum, retirement does not mark the end of the formative process but rather a stage of epistemic continuity with transformative potential for contemporary education.

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Declaration of Generative AI and AI-Assisted Technologies in the Writing Process

In the preparation of this manuscript, ChatGPT (OpenAI, 2026) was used as a supportive tool for improving writing, organizing ideas, and reviewing the linguistic clarity of the text. Its use was limited to assistance in enhancing coherence and readability and did not involve the generation of research results, data analysis, or the formulation of conclusions.

The author ensures that all academic content, theoretical interpretation, and methodological decisions remain his sole responsibility. At all times, the principles of academic integrity were upheld, guaranteeing that the use of AI tools did not replace critical thinking, theoretical reflection, or intellectual authorship.

Accordingly, artificial intelligence was employed as an auxiliary, complementary, and ethically supervised resource within the manuscript development process.

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Mixed Methods Evaluation of a Community-Based Intergenerational Program to Improve Quality of Life, Social Capital, and Generativity Among Elderly in Rural India

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Abstract

This study presents a mixed methods evaluation of Sahjeevan Kendra, a community-based intergenerational program implemented across 18 rural villages in Wardha, Maharashtra, India, under the Health and Demographic Surveillance System (HDSS) of Mahatma Gandhi Institute of Medical Sciences (MGIMS), Sevagram. Conducted from December 2020 to September 2023, the program aimed to improve quality of life, social capital, and generativity among older adults aged 60 years and above through structured intergenerational engagement with children and adolescents. The study employed a stratified simple random sampling design with a total sample of 520 elderly participants from a population of 4,415 identified individuals. Quantitative assessment utilized the WHO Quality of Life BREF (WHOQOL-BREF), the Loyola Generativity Scale, the Social Capital Scale, and a Self-Care Assessment Tool. Qualitative data were gathered through focused group discussions, in-depth interviews, and observation using the Spider Web Method. Quantitative findings showed largely stable scores across program phases, suggesting maintenance of wellbeing despite the challenges of ageing and chronic conditions. Qualitative findings revealed meaningful gains in intergenerational interaction, respect for older adults, self-confidence among master trainers, and community social participation. The program effectively repositioned elderly individuals as active community mentors and caregivers, thereby strengthening their sense of generativity and social roles. Findings demonstrate the feasibility and acceptability of scalable, community-integrated intergenerational models in low- and middle-income country (LMIC) settings.

Keywords: intergenerational program, elderly, quality of life, rural India, mixed methods

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Introduction

Population ageing is a global phenomenon with significant implications for health systems, social structures, and community wellbeing. In India, the proportion of individuals aged 60 years and above is growing rapidly, with rural populations facing compounded challenges including social isolation, limited access to healthcare, and diminishing intergenerational engagement. Elderly individuals in rural communities often experience a gradual withdrawal from meaningful social roles, contributing to a decline in psychological wellbeing and generativity, defined as the concern for and commitment to the next generation.

In rural Maharashtra, this problem manifests visibly across villages where older adults progressively disengage from family and community life. Sahjeevan Kendra, meaning "the centre for co-existing life", was conceived as a community-based response to this challenge, transforming spaces of isolation into inclusive platforms for intergenerational interaction. This study evaluates the implementation and impact of this program using a mixed methods design over three years, examining outcomes across quality of life, social capital, generativity, and self-care among elderly participants.

The objectives of this study were: (1) to implement a structured community-based intergenerational program across rural villages in Wardha; (2) to assess changes in quality of life, social capital, generativity, and intergenerational interaction over three program phases; and (3) to identify facilitating factors and barriers to implementation through qualitative inquiry.

Methodology

Study Design and Setting

The study employed a mixed methods design, integrating quantitative outcome measurement with qualitative process evaluation. The study was conducted in 18 villages in the Wardha district of Maharashtra, India, located within the Health and Demographic Surveillance System (HDSS) catchment area of MGIMS, Sevagram. The study duration was December 2020 to September 2023.

Study Phases

The program was implemented across three sequential phases:

- Phase I involved formative research and the development of training modules grounded in community needs assessment.
- Phase II focused on the implementation of elderly-focused self-care strategies, equipping older adults with knowledge and skills for healthy ageing.
- Phase III centred on community mobilization through "Sahjeevan Melawas" (community gatherings) and collaborative intergenerational activities that brought elderly, children, and adolescents together.

Sampling and Sample Size

A stratified simple random sampling design was employed. A total of 4,415 elderly individuals were identified from the 18 villages: 2,612 in the 60–70 age group and 1,803 aged above 70 years. The final study sample comprised 520 participants.

Assessment Tools

The following standardized instruments were used for quantitative assessment:

(1) WHO Quality of Life BREF (WHOQOL-BREF): a validated multidimensional measure of quality of life across physical, psychological, social, and environmental domains.
(2) Social Capital Scale: measuring dimensions of community participation, trust, and social networks.
(3) Loyola Generativity Scale (LGS): assessing the degree to which elderly individuals express concern for and commitment to the well-being of future generations.
(4) Self-Care Assessment Tool: evaluating the extent to which elderly individuals practise health-promoting self-care behaviours across multiple domains.

Qualitative data were gathered through focused group discussions (FGDs), in-depth interviews (IDIs), and structured community observation using the Spider Web Method, which enabled multidimensional visual mapping of program outcomes across eight identified domains.

Training Cascade Model

A cascade model of community participation was employed to implement the program at scale. Key trainers drawn from MGIMS faculty, district health teams, and elderly community leaders trained master trainers from village health and wellness centres. Master trainers, comprising 20–30 individuals per village, subsequently reached all elderly individuals and households within their communities. This nested structure ensured reach and sustainability of the program.

Program Modules

The intervention comprised three programmatic pillars, each addressing a distinct dimension of intergenerational engagement:

- Pillar I focused on nurturing care for early childhood development (ECD), covering concepts of intergenerational programming, play and communication activities, responsive feeding, conducive home environment, and safety and security. Elderly participants were trained to engage with young children and support caregivers with knowledge drawn from their own experience.
- Pillar II addressed the involvement of elderly individuals in enhancing adolescent life skills. Topics included adolescent health and nutrition, decision-making and assertiveness, confidence-building, avoidance of addiction, and the role of household and community in adolescent wellbeing.
- Pillar III centred on healthy ageing and self-care, covering nutrition, physical activity and healthy lifestyle, management of hypertension and diabetes, addiction prevention, mental health including dementia awareness, self-care for eyes, skin, ears, and oral health, and recognition of danger signs.

Results

Quantitative Findings

Quantitative data were collected at baseline (2020) and at the end of each of the three program phases. Tables 1 through 5 present the findings.

Table 1
Combined Analysis of WHOQOL, Loyola Generativity, and Social Capital Scores for Age Group 60–70 Years

Measure	Baseline (2020)	Phase I	Phase II	Phase III
Total QOL	70.6	70.6	69.3	68.5
Total LG Score	32.3	28.3	30.4	28.0
Total Social Capital	49.1	48.7	49.1	48.4

Table 2
Combined Analysis of WHOQOL, Loyola Generativity, and Social Capital Scores for Age Group > 70 Years

Measure	Baseline (2020)	Phase I	Phase II	Phase III
Total QOL	66.9	65.4	65.5	65.4
Total LG Score	31.8	28.0	28.1	26.1
Total Social Capital	45.2	45.3	45.4	45.5

Table 3
Self-Care Total Score (Mean With Standard Deviation)

Age Group	Phase II	Phase III
60–70 Years	127 (24)	106 (20.3)
> 70 Years	125 (23.9)	103 (20.3)

Table 4
Child-Caregiver Interaction (CCI) Scores

Age Group	Baseline (2020)	Phase I	Phase II	Phase III
60–70 Years	8.61 (3.51)	8.2 (3.94)	9.91 (4.22)	9.13 (4.47)
> 70 Years	9.23 (3.05)	6.0 (4.30)	8.31 (4.89)	7.74 (5.25)

Table 5
Adolescent-Elderly Interaction Scores

Interaction Type	60–70 Yrs Year 2	60–70 Yrs Year 3	> 70 Yrs Year 2	> 70 Yrs Year 3
Discussion and Storytelling	92 (8.8%)	99 (9.5%)	78 (7.5%)	84 (8.1%)
Adolescents Helping Elderly	74 (7.1%)	66 (6.3%)	67 (6.4%)	63 (6.1%)
Love and Respect to Elderly	68 (22.9%)	65 (21.9%)	79 (26.6%)	78 (26.3%)

Across both age groups, quality of life scores remained broadly stable over the three program phases, with minor declines consistent with natural ageing trajectories. Social capital scores showed minimal variation, suggesting the program successfully maintained community connectedness over time. Loyola Generativity scores showed some fluctuation but remained within a consistent range, indicating that elderly participants maintained a sustained orientation toward the next generation throughout the program. Self-care scores declined between Phase II and Phase III, likely reflecting increasing health challenges among older participants. Child-caregiver interaction scores showed an overall improvement trend, most notably in the 60–70 age group.

Qualitative Findings

Qualitative data from FGDs, IDIs, and community observations were analysed thematically and represented visually using the Spider Web Method across four stakeholder groups: members of Sahajeevan Samanway Samiti (community coordination committees), caregivers, adolescents, and elderly participants themselves. Eight domains were assessed:

1) Participation of the elderly in ECD and adolescent well-being activities at family and community levels
2) Improvement in interaction between two generations
3) Respect for elderly and their opinions in the family
4) Self-confidence of master trainers in the village
5) Ability of master trainers to reach elderly individuals
6) Increased participation of elderly in village governance
7) Bonding and interaction of elderly with peer groups
8) Transfer of skills and knowledge from elderly to younger generations.

Qualitative findings indicated substantial improvements across all eight domains, with particularly strong gains in intergenerational respect, self-confidence among community trainers, and the perception of elderly individuals as knowledge holders and mentors.

Facilitating Factors

Several contextual factors facilitated successful program implementation. The provision of adequate physical venues and financial support from Gram Panchayats (village governance bodies) enabled smooth execution of activities. The strategic use of cultural festivals such as Ganpati, Durga Devi, and Datta Jayanti created natural gathering points for community engagement. The formation of dedicated elderly groups and their integration with pre-existing community structures such as Bhajan (devotional singing) groups and Self-Help Groups extended program outreach organically. The organisation of intergenerational events

including drawing competitions, quiz contests, rangoli contests, and mother-in-law and daughter-in-law fairs stimulated cross-generational interest and participation.

Barriers to Implementation

The program also encountered several implementation barriers. Loss of daily wages during daytime program activities limited participation among economically active elderly individuals. Health issues and forgetfulness among some participants affected attendance and retention of training content. Financial constraints periodically disrupted the execution of program activities. The high use of mobile devices and television by children and adolescents reduced the quality and frequency of intergenerational interactions in some households. In some families, parents did not engage with or value the knowledge shared by elderly participants following training, which caused frustration among trainers. Seasonal logistical challenges during the rainy season and the prolonged duration of some training sessions also presented difficulties for older participants.

Community Impact

Qualitative testimonies powerfully illustrated the programme's community-level impact. One male elderly participant from Wabgaon recounted how his granddaughter, after attending programme activities, began discarding his tobacco as an expression of her health awareness, demonstrating the bidirectional nature of intergenerational learning. A peer trainer from Mahakal noted that children from nuclear families had begun expressing a desire for their grandparents to live with them, indicating a strengthening of intergenerational bonds that transcended the formal programme space. These narratives underscore the programme's capacity to effect meaningful attitudinal and behavioural change at the household level.

Discussion

This study demonstrates that a community-based intergenerational programme implemented in rural Maharashtra over three years was feasible, acceptable, and could be sustained through a cascade training model engaging community members at multiple levels. The programme successfully repositioned elderly individuals from passive recipients of care to active contributors of community knowledge and mentors to younger generations, a shift with significant implications for generativity, social capital, and psychological wellbeing.

The broadly stable quantitative scores across programme phases are an important finding. Rather than indicating programme failure, maintenance of scores in the context of a longitudinal study with an ageing population represents a meaningful outcome. Ageing is typically associated with declining quality of life, increasing social withdrawal, and diminishing generativity. The fact that WHOQOL-BREF, Social Capital, and Loyola Generativity scores remained largely stable across three years suggests that the programme may have buffered the natural decline associated with ageing and chronic disease progression.

Qualitative findings provide richer insight into the programme's mechanisms of change. Increased intergenerational interaction, greater respect for elderly community members, and a strengthened sense of purpose among older adults are consistent with established theories of successful ageing, including Erikson's concept of generativity and activity theory. The cascade training model proved effective in extending programme reach to all households, and

the integration of the programme with existing community structures such as festival gatherings and self-help groups enhanced sustainability.

The programme's approach aligns with growing global evidence supporting intergenerational models as a cost-effective strategy for addressing both the social needs of older adults and the developmental needs of children and adolescents, particularly in resource-limited settings. This study extends that evidence base to rural LMIC contexts where institutional intergenerational programmes are scarce and community-based approaches may be the most viable and culturally appropriate modality.

Conclusion

The Sahjeevan Kendra intergenerational programme demonstrated that a structured, community-delivered intervention can maintain and support wellbeing among rural elderly populations over multiple years, while simultaneously strengthening social ties across generations. The cascade training model, the integration with existing community platforms, and the involvement of local governance bodies were key enablers of implementation and sustainability.

While quantitative gains were modest, the qualitative evidence of enhanced intergenerational interaction, restored community roles for elderly individuals, and attitudinal change at the household level represents meaningful programme impact. Future research should incorporate control groups to establish causal attribution, employ measurement tools with greater sensitivity for rural geriatric populations, and evaluate cost-effectiveness to support scaling decisions. The model holds significant potential for replication in comparable rural LMIC settings where community-based solutions to population ageing are urgently needed.

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Declaration of Generative AI and AI-Assisted Technologies in the Writing Process

The authors declare that ChatGPT was used only for language polishing and improving readability of the manuscript. The main content, including study design, data collection, analysis, results and conclusions are completely done by the authors. All ideas and interpretation are original work of the authors. The authors take full responsibility for accuracy and correctness of the content.

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The Confucian SST-SOC Model: Technology Adaptation as Ethical Performance Among Older Adults in China

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Abstract

Social connectivity depends on digital technologies, but in collectivist societies such as China, older adults experience a strong participation divide. Models that are based on individualistic assumptions, like the Technology Acceptance Model (TAM), do not sufficiently explain adaptation behaviour based on relational ethics. This gap is filled through a current study, which investigates the importance of Confucian ethics, filial piety (Xiao), face (Mianzi), and harmony (Hexie) in establishing technology adaptation among older adults. We propose the Confucian SST-SOC Model of Technology Adaptation, integrating Socioemotional Selectivity Theory (SST) and Selection, Optimisation, and Compensation (SOC) theory with Confucian principles to reframe cognitive and affective appraisals. A mixed-methods study with 343 older Chinese social media users revealed through structural equation modelling (CFI = .96, RMSEA = .05) that culturally reframed appraisals predict four adaptation pathways: exploration to maximise benefits (EMSMB), exploitation to satisfy benefits (ESSMB), exploration to revert (ER), and avoidance (ASM). Thematic analysis of 287 open responses confirmed that behaviours are motivated by Xiao, Mianzi, and Hexie. Findings show technology adaptation operates as a culturally embedded ethical practice rather than mere technical acquisition. The study offers a theoretical framework to challenge universalist models and provides practical implications for culturally resonant gerontechnology design and policy.

Keywords: Confucian ethics, technology adoption, older adults, social media, mixed-methods

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Introduction

The demographic change in the whole world is the transition to the ageing of the population accompanied by the rapid pace of digitalisation. Surgeons of the predominant frameworks like the Unified Theory of Acceptance and Use of Technology (UTAUT) presuppose the rationality of the individual and independent choice (Venkatesh et al., 2003). The models are, however, inadequate to explain behaviours in collectivist cultures that are not Western (Srite & Karahanna, 2006; Straub et al., 1997). The issue is not just a cultural one but ontological. These models presuppose an independent self-construal. They do not remember the relational and moral structure of Confucian communities (Markus & Kitayama, 1991).

One obvious advantage of digital technologies in ageing is evident (Sixsmith et al., 2022). Nevertheless, they are usually designed without taking into account the fact that cultural values transform such simple concepts as usefulness and risk (Gran et al., 2021).

We cease to model single adoption and start to analyse the culturally embedded practice. Previous studies have recorded behavioural management in Chinese older adults (Fang, 2022; Lei, 2023). Nevertheless, there is a severe lapse. None of the theories is a combination of macro-level cultural scripts and micro-level psychological processes. Three weaknesses afflict existing models. The Socioemotional Selectivity Theory (SST) assumes that older adults focus on emotional achievements (Carstensen et al., 1999). However, it does not say how collectivist values such as Xiao (filial piety) transform the meaning of emotion into family duties. Selective Optimisation with Compensation (SOC) considers the adaptation as personal resource management (Baltes & Baltes, 1990). It ignores the way Confucian ethics redistribute the agency between generations. The parental privacy settings are frequently addressed by the adult children. Lastly, the current models consider affective appraisals such as fear and trust as generic constructs (Muhammad et al., 2021).

We propose the Confucian SST-SOC Model of Technology Adaptation. This model is based on three ethics of Confucius. Xiao (filial piety) inserts a hierarchically obligatory hierarchy in a moral framework. Contrary to the Western cultural values of a family, the filial deeds are self-realisation but not the exchange (Ames & Rosemont, 1998). Mianzi (social face) as a social asset is an asset belonging to a family (Hwang, 2011). The embarrassment of an older adult as he/she commits a technological error becomes a family issue. Adult children might be obliged to make apologies to their network. The harmony (hexie) goes beyond interpersonal agreement. According to the Analects, the utmost value in practising ritual is harmony (Lau, 1979). This norm is applied to the adoption of technology by working in two directions. They are disintegration avoidance and harmony enhancement (Leung et al., 2002). Relational equilibrium is broken by technologies that break intergenerational roles. Those who default on this establish social risk upon themselves. Such constructs create a culture matrix.

Our model integrates these ethics with SST and SOC. It posits that culturally shaped goals direct individuals toward four distinct adaptation pathways. First, Exploration to Maximise Benefits (EMSMB). This involves proactive innovation driven by Xiao and operationalised through Optimisation. Second, Exploitation to Satisfice Benefits (ESSMB). This involves conservative use guided by Hexie and Mianzi through routine based Optimization. Third, Exploration to Revert (ER). This involves adaptive reversion to traditional methods motivated by Mianzi and Hexie via Compensation. Fourth, Avoidance of Social Media (ASM). This involves cautious limitation driven by all three values through Loss-based Selection.

We investigate two research questions. RQ1 (Content). How do Confucian values (Xiao, Mianzi, Hexie) reconstitute the cognitive and affective appraisals that shape strategic social media engagement? RQ2 (Process). How do these culturally reconstructed appraisals predict the four adaptation pathways statistically? How does qualitative data provide complementary interpretive validation?

We follow the rewriting of the Confucian values in technology acceptance psychology. Instead of using qualitative data as illustration, we apply thematic analysis to confirm quantitative measures of culturally particular constructs. This methodological reciprocity is not common in cross-cultural gerontechnology. We recognise the existence of levers such as Xiao and Mianzi for the designers. We redefine digital literacy as a skill set, but not an acquisition set, rather as ethical conduct. Finally, this piece of writing supports decolonial gerontechnology. It is the true digital inclusion that should establish itself on the concept of relational autonomy as opposed to the imported models of individual optimisation when considering non-Western situations.

Literature Review

Rational choice models have been widely used in technology acceptance. TAM (Davis et al., 1989) and UTAUT (Venkatesh et al., 2003) are the most notable ones. These models describe adoption based on cognitive beliefs at an individual level. They are mostly concerned with the perceived usefulness and ease of use. Due to their parsimony, they have found extensive application in the research of gerontechnology. This encompasses research on older adults in China (Deng & You, 2020). Nevertheless, there is a regular anomaly when these models are used for ageing populations. One of the meta-analyses demonstrates that, at late seventies adulthood, the linear dependence between chronological age and TAM-based acceptance loses significance (Hauk et al., 2018).

Physically, TAM and UTAUT consider operational impediments as one construct. They refer to it as perceived ease of use (Davis et al., 1989). This practice clouds the nature of age-associated deteriorations in the way human-computer interaction (Felber et al., 2024). This is not an omission of measurement, but an ontological weakness (Bagozzi, 2007). The models conceptualise capabilities as constant perceptions instead of dynamic constraints.

The prevailing TAM-UTAUT tradition ignores the issue of affective factors. It disregards the exchanges among situational elements and emotional states, which are the catalysts of mobile social media use (Masur et al., 2022). TAM2 and UTAUT have no emotional constructs in the original version of TAM (Davis et al., 1989; Venkatesh & Davis, 2000; Venkatesh et al., 2003). Computer anxiety is only included in the list of distal predictors in TAM3 (Venkatesh & Bala, 2008). UTAUT2 also downsizes the hedonic motivation to a generic driver (Venkatesh et al., 2012). This trend continues with even the models created to work with older adults. According to the Senior Technology Acceptance Model (STAM), gerontechnology anxiety is one of the most important antecedents (Chen & Chan, 2014). However, it does not differentiate anxiety into a single undifferentiated construct.

Third, the models treat socio-cultural influence reductively. Bagozzi (2007) critiques that “subjective norm” reduces the rich socio-cultural environment to a simple perception of social pressure. Empirically, Schepers and Wetzels’ (2007) meta-analysis confirms heterogeneity in subjective norm effects. To capture culture as a constitutive force, we turn to script theory (Schank & Abelson, 1977). Internalised cultural scripts serve as shared templates. They guide cognition and action (D'Andrade, 1992). The central limitation of applying Western models to

collectivist cultures is clear. They treat adoption as an individual rational choice and overlook relational determinants (Srite & Karahanna, 2006; Straub et al., 1997). In East Asian Confucian contexts, the self-concept is interdependent (Markus & Kitayama, 1991).

Fang (2022) shows that Chinese older adults guided by hexie and mianzi scripts curate harmony-oriented Moments posts. Lei (2023) identifies three script-driven strategies: buffering (displaying family harmony), reinforcing (sharing hometown nostalgia), and expanding (exchanging renqing). They are the ones that expose the strategic behaviours and Confucian ethics. But this is where the problem lies in: how the rich cultural observations can be incorporated into a dynamic model of adaptation.

Theoretical Framework: The Confucian SST-SOC Model of Technology Adaptation in Older Adults

The existing models fail to provide sufficient theoretically foundational models of the culturally embedded nature of cognitive appraisals and do not define specific. The Confucian SST-SOC Model treats adaptation as a culturally entrenched, ethical practice and not mastery in its own right. It combines SST (Carstensen et al., 1999) and the SOC model (Baltes & Baltes, 1990) in explaining the restructuring of appraisals through three Confucian moral principles. These include Xiao (filial piety), He (harmony), and Mianzi (social face).

SST postulates that older adults put more emphasis on emotionally significant goals. This value is expressed in our model in Confucian goals. Among them is the need to build stronger bonds with family (Xiao) and the need to maintain familial face (Mianzi). The SOC approaches describe the manner in which people use resources to accomplish these culturally constructed objectives.

The model projects culturally mediated SST goals and SOC strategies on four adaptation pathways. Table 1 presents these pathways. EMSMB represents proactive innovation driven by Xiao via Optimization. ESSMB represents conservative use guided by Hexie and Mianzi via routine Optimisation. ER represents adaptive reversion motivated by Mianzi and Hexie via Compensation. ASM represents cautious limitation driven by all three values via Loss-based Selection.

We hypothesise specific relationships between these appraisals and the four adaptation pathways.

Table 1
Operationalisation of Adaptation Pathways in the Confucian SST-SOC Model

Latent Construct	Definition	Integrated Mechanism (Value→SST Goal→SOC Strategy)	Hypothesis Linkage
EMSMB	Proactive innovation to strengthen family bonds.	Xiao entails a pursuit of deeper bonds, culminating in optimisation through exploration	H1, H3, H5, H9
ESSMB	Conservative use to maintain stability and minimise risk.	Hexie and Mianzi→Pursuit of predictability and comfort→Optimization (via routine)	H2, H4, H6, H10
ER	Reverting to traditional methods when facing challenges.	Mianzi and Hexie→Goal of preserving harmony and dignity→Compensation (alternative means)	H7, H11, H13
ASM	Limiting use to protect reputation and autonomy.	Xiao, Mianzi, and Hexie→Goal of avoiding relational loss→Selection (loss-based)	H8, H12, H14

Culturally Reconstructed Appraisals

In the Confucian SST-SOC framework, Perceived Opportunity (PO) shifts from individual to familial utility. Technology value is judged by its capacity to fulfil Xiao and preserve Hexie (Ames & Rosemont, 2011; Leung et al., 2002) (see Table 2). Xiao-driven PO activates SST goals of deepening family bonds via Optimisation (EMSMB), as when older adults explore new features to strengthen family ties (Ma et al., 2023). Hexie-guided PO prioritises relational stability via routine Optimisation (ESSMB). Therefore, we hypothesise:

H1: PO, shaped by Xiao-driven familial utility, positively predicts EMSMB.

H2: PO, guided by Hexie's harmony imperative, positively predicts ESSMB.

Table 2
Key Differentiation From Western PO

Dimension	Western PO	Confucian PO	Theoretical Anchoring
Usefulness	Personal productivity	Fulfilling *Xiao* through family bonding	Confucian Ethics (Ames & Rosemont, 2011)
Ease of Use	Individual technical proficiency	Relational simplicity (preserving *Hexie*)	HeXie Management Theory (Leung et al., 2002)
Task Efficiency	Time or effort savings for self	Minimising relational friction	HeXie Management Theory (Leung et al., 2002) & SST (Carstensen et al., 1999)
Relative Advantage	Competitive individual benefit	Superiority in fulfilling *Xiao* and *Hexie*	Integrated Confucian SST-SOC Framework

Perceived Social Influence (PSI) is redefined as an external pressure by peers, to an “nternalized, family-based moral requirement. The reason behind this change can be attributed to the necessity to preserve Mianzi and retain Hexie (Hwang, 2011; Leung et al., 2002), in which social influence is already a moral necessity to save the integrity of the family (see Table 3).

In the event that PSI is fueled by the desirable management of family Mianzi, it diverts funds towards the improvement of familial interaction, favouring EMSMB. On the other hand, when PSI is based on a commitment to preserving Hexie, it drives a behaviour that creates stability and decreases risk, resulting in a preference for ESSMB. Therefore, we hypothesise:

H3: PSI with the motivation of family *Mianzi* has a positive forecast of EMSMB.

H4: The presence of motivation of PSI by the need to preserve Hexie positively forecasts ESSMB.

Table 3
Key Differentiation From Western PSI

Dimension	Western PSI	Confucian PSI	Theoretical Anchoring
Source of Influence	Peers, colleagues, society	Immediate and extended family	Confucian Role Ethics (Ames & Rosemont, 2011)
Nature of Obligation	Compliance with social expectations	Fulfilment of relational duties (e.g., Xiao)	Confucian Role Ethics (Song, 2024)
Primary Motivation	Social conformity, status acquisition	Safeguarding Mianzi and maintaining Hexie	Face Dynamics (Hwang, 2011) & HeXie Management Theory (Leung et al., 2002)

As shown in Table 4, Perceived Control (PC) transitions from a focus on individual self-efficacy to relational efficacy, oriented toward preserving *Hexie* (Leung et al., 2002) and

achieving intergenerational balance (fulfilling Xiao while safeguarding Mianzi) (Ames & Rosemont, 1998; Hwang, 2011). Control is redefined as the ability to manage technological engagement through strategic delegation and simplification, to achieve these relational goals (Guo & Guo, 2012).

PC based on intergenerational balance (Xiao and Mianzi) promotes resource gain, directly activating EMSMB and reducing the perceived threats that drive ASM. In contrast, PC based on Hexie focuses on preventing loss, fostering ESSMB and reducing the need for compensatory behaviours (ER). Therefore, we hypothesise:

H5: PC based on intergenerational balance positively predicts EMSMB.
H6: PC based on harmony preservation positively predicts ESSMB.
H7: PC based on harmony preservation negatively predicts ER.
H8: PC based on intergenerational balance negatively predicts ASM.

Table 4
Key Differentiation From Western PC

Dimension	Western PC	Confucian PC	Theoretical Anchoring
Locus of Control	Internal: belief in one's own skills.	Relational efficacy: Confidence from managing familial networks.	Confucian Role Ethics (Ames & Rosemont, 1998) & Cross-cultural Psychology (Guo & Guo, 2012)
Primary Goal	Personal task accomplishment.	1. Harmony preservation (Hexie) 2. Intergenerational balance (Xiao, Mianzi)	1. HeXie Management Theory (Leung et al., 2002) 2. Confucian Ethics (Ames & Rosemont, 1998) & Face Dynamics (Hwang, 2011)
Behavioural Manifestation (SOC)	Independent action and personal mastery.	Strategic delegation and simplification as relational maintenance.	SOC Model (Baltes & Baltes, 1990)

Perceived Enjoyment (PE) transitions from personal amusement to the relational joy derived from fulfilling core cultural duties (see Table 5). It acts as an effective signal of successfully performing one's familial duties.

PE rooted in familial fulfilment (enacting Xiao and enhancing Mianzi) motivates active EMSMB. Conversely, PE rooted in harmonious gratification (preserving Hexie) encourages ESSMB. Therefore, we hypothesise:

H9: PE derived from familial fulfilment positively predicts EMSMB.
H10: PE derived from harmonious gratification positively predicts ESSMB.

Table 5
Key Differentiation From Western PE

Dimension	Western PE	Confucian PE	Theoretical Anchoring
Core Driver	Personal gratification, fun.	1. Relational fulfilment (Xiao, Mianzi) 2. Harmonious gratification (Hexie)	1. Confucian Role Ethics (Ames & Rosemont, 2011) & Face Dynamics (Hwang, 2011) 2. HeXie Management Theory (Leung et al., 2002)
Nature of Engagement	Exploration for personal entertainment.	Engagement for harmonious gratification (Hexie).	SST (Carstensen et al., 1999) & HeXie Management Theory (Leung et al., 2002)
Primary Outcome	Individual pleasure.	Affective reward from familial fulfilment or harmonious gratification.	Integrated Confucian SST-SOC Framework

Fear

The emotion of fear is reframed as an anticipatory anxiety about failing in one's core relational duties (Leung et al., 2002), damaging Mianzi (Hwang, 2011), or contravening Xiao (Ames & Rosemont, 2011). This culturally salient fear motivates specific SOC strategies to avert threats to relational integrity (see Table 6). Trust and perceived risk are routinely treated as key factors shaping user decisions. Drawing on Venkatesh and Bala (2008), trust within TAM3 is defined as the extent to which a user believes the system is reliable and secure. Following Featherman and Pavlou (2003), perceived risk is viewed as a multi-faceted construct that directly inhibits adoption intentions and weakens the positive effect of perceived ease of use on perceived usefulness.

Fear driven by threats to Hexie and Mianzi motivates compensatory actions, which positively predict ER. In contrast, fear driven by becoming a burden promotes strategic disengagement, which positively predicts ASM. Therefore, we hypothesise:

H11: Fear driven by threats to Hexie and Mianzi positively predicts ER.

H12: Fear driven by threats to Xiao positively predicts ASM.

Table 6
Key Differentiation From Western Fear

Dimension	Western Fear	Confucian Fear	Theoretical Anchoring
Locus of Fear	Personal risk (e.g., data loss).	Relational integrity: Violating Xiao, Hexie, or Mianzi.	Confucian Role Ethics (Ames & Rosemont, 2011), HeXie Management Theory (Leung et al., 2002), and Face Dynamics (Hwang, 2011)
Nature of Threat	Direct individual consequence.	Anticipatory social disharmony and role-based ethical failure.	Confucian Role Ethics (Ames & Rosemont, 2011)
Behavioural Manifestation (SOC)	Avoidance of the technology.	Strategic adaptation (e.g., reverting) to fulfil obligations.	Integrated Confucian SST-SOC Framework

Trust in Confucian Contexts

Trust is redefined from confidence in a technology's functional reliability to relational confidence in systems that uphold core ethical values (see Table 7). It is evaluated based on the technology's capacity to affirm familial authority and fulfil Xiao (Ames & Rosemont, 2011), and to promote collective stability and Hexie (Leung et al., 2002). Empirical studies have confirmed that technologies facilitating family interaction are highly valued for these purposes (Ma et al., 2023).

Trust that manifests as familial assurance (aligning with Xiao) reduces the need for alternative communication methods, thereby negatively predicting ER. Trust that manifests as collective consensus (affirming Hexie) alleviates fears of being a burden or causing reputational harm, thus negatively predicting ASM. Therefore, we hypothesise:

H13: Trust, manifested as familial assurance, negatively predicts ER.

H14: Trust, manifested as collective consensus, negatively predicts ASM.

Table 7
Key Differentiation From Western Trust

Dimension	Western Trust	Confucian Trust	Theoretical Anchoring
Locus of Trust	The technology's functional reliability.	The platform's congruence with Xiao and Hexie.	Confucian Ethics (Ames & Rosemont, 2011) & HeXie Management Theory (Leung et al., 2002)
Basis of Trust	Technical safeguards, brand reputation.	Familial endorsement and collective consensus.	SST (Carstensen et al., 1999) & Face Dynamics (Hwang, 2011)
Behavioral Outcome	Continued use for personal utility.	Reduced reliance on fallbacks (ER) and diminished avoidance (ASM).	Integrated Confucian SST-SOC Framework

Method

Study Design and Survey Instrument

We used a quantitative survey, accompanied by exploratory qualitative data. This QUAN-qual design employs qualitative knowledge to complement interpretive validation (Creswell & Plano Clark, 2017). To ascertain linguistic and psychological equivalence, we did a stringent translation and back-translation exercise. This was done by a group of bilingual linguistic professionals (Brislin, 1986). The translation was then subjected to intensive pretesting of the survey. To achieve content validity and clarity, we interviewed a small group of Chinese older adults (n = 10) in cognitive interviews (Dillman et al., 2014).

The Tencent Questionnaire was used to conduct the survey online on 343 older adults (65 years and above) in China. The mean age was 74 years. There was informed consent of participants. They were social media users who lived in China. We used convenience sampling. We weeded out speeders and those who failed to pass attention tests.

Sample Characteristics

The last sample consisted of 56.3 and 43.7% men and women. Educational levels were different (16.9% less than high school to 4.7% masters+). There was 44% rural, 30% third-tier cities, 14.6% first-tier and 11.4% second-tier geographic distribution. Only 3.5% were less than 2 years of experience with mobile phones. 43.1% had more than 10 years of experience.

Measures

Each of the items was measured with a five-point Likert scale (1 = strongly disagree, 5 strongly agree). The operationalisations of the constructs involved in the Confucian SST-SOC Model were the measurement scales (Appendix A).

Four items representing family duty-oriented utility were used by PO. Sample question: Social media allows you to be closer to your family. PSI used three items capturing internalised ethical obligation to safeguard Mianzi and maintain Hexie. Example: "I feel pressured by my children/grandchildren to learn social media." PC used three items reflecting relational efficacy. Example: "I confidently ask family for help with social media." PE used three items capturing relational joy. Example: "I enjoy seeing/sharing family updates on social media." Fear used three items capturing anticipatory anxiety about violating relational duties. Example: "I worry social media mistakes will require family help." Trust used three items reflecting relational confidence. Example: "I trust platforms my family recommends."

EMSMB and ESSMB items were adapted from established technology adaptation scales (Bala & Venkatesh, 2016; Muhammad et al., 2021). We rigorously contextualised these to reflect Confucian motivations. We developed ER and ASM items specifically for this study. These capture unique compensatory and loss-based selection behaviours within the Confucian context.

An open-ended question at the end asked the following. "Please describe the main reasons behind your choices of using or not using social media features." We analysed responses using thematic analysis (Braun & Clarke, 2006). This assessed whether self-reported motivations aligned with the Confucian ethical concepts hypothesised by our model.

Validity and Reliability Assessment

We established construct validity through confirmatory factor analysis (CFA). The measurement model demonstrated excellent fit. Chi-square/df was 1.86. CFI was 0.96. TLI was 0.948. RMSEA was 0.05. SRMR was 0.05. All standardised factor loadings exceeded 0.60 ($p < .001$). We confirmed discriminant validity using the Fornell-Larcker criterion. The square root of AVE for each construct exceeded its correlations with other constructs.

We assessed construct reliability using Cronbach's alpha and composite reliability (CR). All constructs achieved CR values above 0.70. The exception was Avoidance of Social Media (ASM). ASM had a CR of 0.66 and an AVE of 0.49. Although reliability is modest, ASM is adequately grounded in theory and has sufficient factor loadings. This indicates that it is challenging to measure subtle culturally-influenced behaviours using a small number of items.

Analytical Strategy

First, the hypothesised factor structure was supported by the CFA model. Second, the structural model was used to test all the hypothesised paths (H1–H14). Our SES, technology literacy, age and gender were controlled. The estimation was done by maximum likelihood estimation (1,000 bootstrap resamples). This produced strong standard errors and confidence intervals (Yung & Bentler, 1996). The structural model fitted well. CFI was 0.96. RMSEA was 0.05. SRMR was 0.06.

Results

Quantitative Hypothesis Testing

The structural model demonstrated good fit (CFI = 0.96, RMSEA = 0.05, SRMR = 0.06; see Table 8).

Cognitive Appraisals and Adaptation Pathways

PO drove adaptive use. It positively predicted EMSMB ($\beta = 0.190$, $p < .001$) and ESSMB ($\beta = 0.184$, $p < .01$). These findings support H1 and H2. PSI strongly influenced EMSMB ($\beta = 0.419$, $p < .001$) and ESSMB ($\beta = 0.265$, $p < .05$). These findings support H3 and H4. PC showed a complex pattern. It positively predicted EMSMB ($\beta = 0.146$, $p < .05$) and ESSMB ($\beta = 0.154$, $p < .05$). It was negatively associated with ER ($\beta = -0.199$, $p < .01$). These findings support H5, H6, and H7. However, PC did not predict ASM ($\beta = 0.111$, $p > .05$). We therefore reject H8.

Affective Appraisals and Adaptation Pathways

PE strongly predicted EMSMB ($\beta = 0.253$, $p < .01$) and ESSMB ($\beta = 0.396$, $p < .001$). These results confirm H9 and H10. Fear significantly increased ER ($\beta = 0.220$, $p < .01$) and ASM ($\beta = 0.558$, $p < .001$). These results support H11 and H12. Trust reduced ER ($\beta = -0.190$, $p < .01$) and ASM ($\beta = -0.305$, $p < .001$). These results support H13 and H14.

Qualitative Thematic Analysis

An analysis of 287 valid open-ended responses, done by thematic analysis, was conducted to bring out narratives that put the quantitative findings into perspective. Four key themes emerged.

Theme 1: Technology as a Tool for Filial Piety (Xiao)

Staying in touch with the children in the distance was mentioned as one of the main motivational factors. One man aged 74 years indicated the following. I have heard about WeChat video calls so that I could see my daughter in Shanghai. The fact that she is fine helps me to relax. It's what parents should do.” This is a manifestation of Xiao-motivated utility and family satisfaction. It is a motivator of EMSMB and ESSMB behaviour.

Theme 2: Preservation of Family Face (Mianzi)

The participants who had participated in ASM cited that they did not want to bother children or make them lose face. One 71-year-old female gave the following. “I do not post anything myself. I will not do it right, I will tell something bad, and my son will need to apologise on my behalf. It is preferable to look and not to rock the boat. This is the fear of ASM predicted by Mianzi.

Theme :3 The Imperative of Relational Harmony (Hexie)

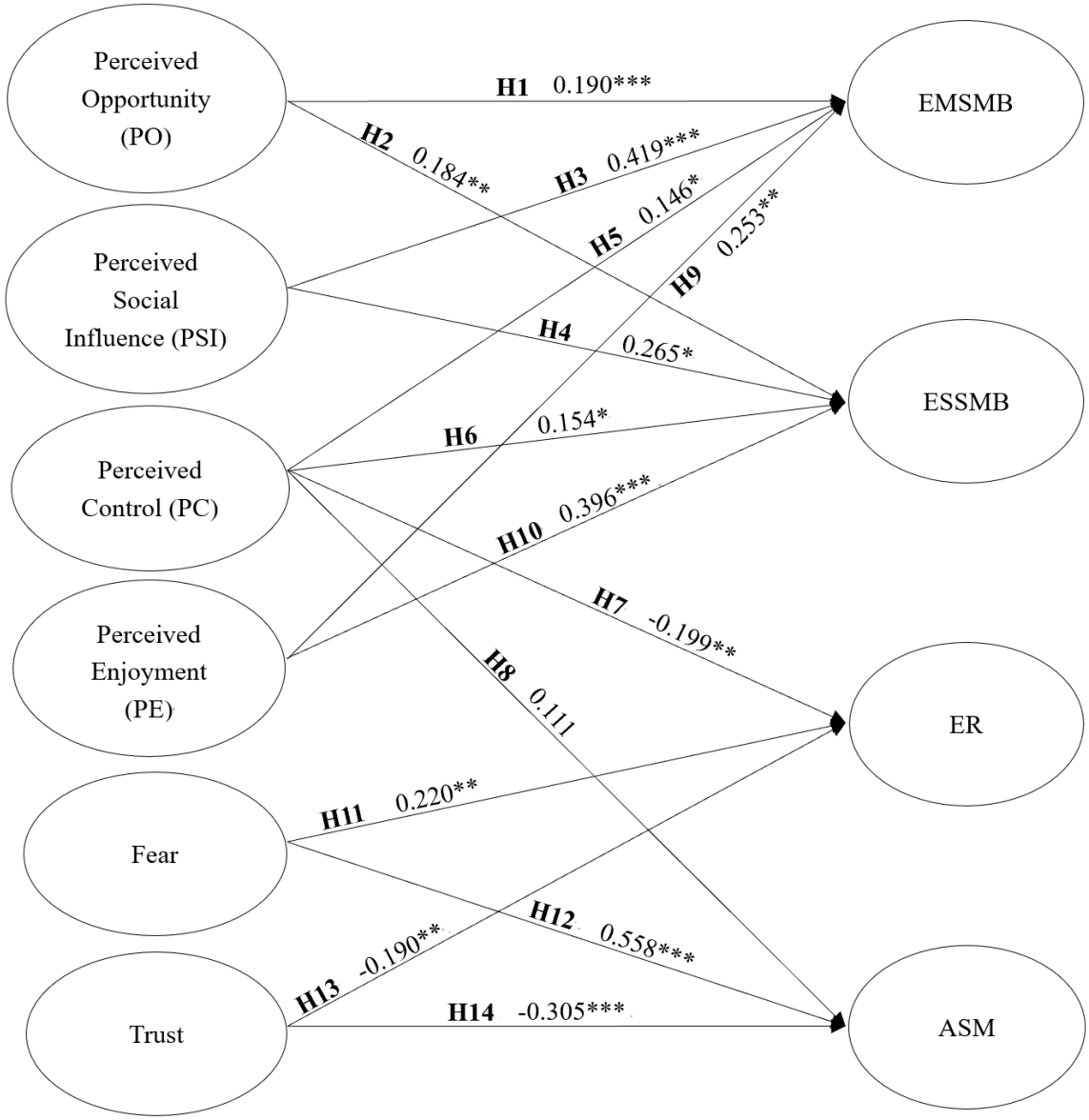
Most of them adhered to the methods taught by their family members. One gentleman aged 68 years noted the following. My grandson had everything prepared for me. I just have the buttons he demonstrated to me. I do not touch other objects in order not to delete our family chat or feel confused. This represents ESSMB, which is Hexie-driven. The respondents also mentioned that they would revert to old practices to ensure that there is harmony. One 76-year-old female made the following statements. “If the video call does not work, I just call them directly. It's more reliable. The most important thing is that we can talk, not how we talk. Why let a technical problem ruin a good conversation?” This highlights ER as compensation to restore Hexie.

Theme 4: Relational Trust as Facilitator

Family approval reduced anxiety. One 72-year-old male stated the following. “I only use the apps that my children say are safe and that everyone in the family is using. If they all use it and recommend it, I feel it must be okay, and I am not afraid to try it.” This supports that trust negatively predicts ASM and ER.

Figure 1

Analysis Results



Note. *: p < .05; ** p < .01; ***: p < .001

Table 8
Summary of Hypothesis Testing Results

Hypothesis	Path	β	p-value	Supported or not
H1	PO → EMSMB	0.190	< .001	Yes
H2	PO → ESSMB	0.184	< .01	Yes
H3	PSI → EMSMB	0.419	< .001	Yes
H4	PSI → ESSMB	0.265	< .05	Yes
H5	PC → EMSMB	0.146	< .05	Yes
H6	PC → ESSMB	0.154	< .05	Yes
H7	PC → ER	-0.199	< .01	Yes
H8	PC → ASM	0.111	> .05	No
H9	PE → EMSMB	0.253	< .01	Yes
H10	PE → ESSMB	0.396	< .001	Yes
H11	Fear → ER	0.220	< .01	Yes
H12	Fear → ASM	0.558	< .001	Yes
H13	Trust → ER	-0.190	< .01	Yes
H14	Trust → ASM	-0.305	< .001	Yes

Discussion

This study examines technology adaptation among older adults in China. CFI was 0.96. RMSEA was 0.05. SRMR was 0.06. This confirms that culturally restructured cognitive and affective appraisals predict the four distinct adaptation pathways. These findings were placed in context through qualitative analysis. The stories of the participants can be attributed to the Confucian ethical principles that are assumed to be the motivating factors of behaviours.

To answer RQ1, in our model, the fundamental variables recalibrated by Xiao, Mianzi, and Hexie are PO, PSI, PC, PE, fear, and trust. In the case of RQ2, we established that every appraisal has a distinct predictive value of EMSMB, ESSMB, ER, and ASM. The interpretive validation was complementary to qualitative data.

These theories have their underlying assumptions on an independent self-construal (Markus & Kitayama, 1991). An interdependent self-construal is what controls technology adoption among Confucian societies.

Our statistics dispute this assumption. It was also found that the restructuring of PO around the family and friendly relations was a strong predictor of both exploratory (EMSMB) and exploitative (ESSMB) use. This observation shows that usefulness is evaluated in a relative manner. It empirically proves the theoretical correlation between culture and cognition as developed by Oyserman (2017). The technology was rated by the participants in terms of effectiveness in the implementation of the filial functions. One of the participants was able to record the following. I knew that I could use WeChat video calls to meet my daughter. It's what parents should do.”

TAM and UTAUT are grounded on the rationality and utility maximisation of an individual (Bala & Venkatesh, 2016; Venkatesh et al., 2003). The internalised moral imperative to maintain the position in the system of the family is manifested in our model. This confirms the idea of Embeddedness developed by Schwartz (2012). It prioritises values that foster social peace and social good. On the quantitative side, we had good motivations that were based on relational fulfilment. EMSMB and ESSMB were positively predicted by Perceived Enjoyment

(0.253 and 0.396, respectively, p < .01/.001). There was also high relational risk avoidance. There was a positive prediction of ASM by fear (= 0.558, p < .001). Theme 2 qualitatively describes avoidance as a moral concern as opposed to a technical deficit. One of the participants was able to record the following. I am afraid I shall not do it right, and my son would have to make up his mind to be sorry on my behalf. This result can be directly related to the literary criticism of the labelling of such behaviours as a mere resistance or low self-efficacy (Mannheim et al., 2019). The question of the motive of adoption is no longer What is in it for me? to "Will this assist me in performing my task and securing my family?

This process realises cultural schemas (D'Andrade, 1995). They operate as the cognitive-affective filters to determine the compatibility of cultural aspects of technology features. This process is shown in Theme 3. It demonstrates the urgency of the relationship harmony (Hexie). Perceived Control (redefined as relational control) encouraged stable use quantitatively. It was also adversely related to Reversion (ER). The Hexie schema can be used to explain this. Routines of the participants were strict. One noted the following. I just operate the buttons he demonstrated to me. Others would go back to familiar ways of ensuring that they remain in harmony and not conflict. This shows that the appraisal of control is conceived of as the ability to sustain the relational stability and not personal mastery. On the same note, Theme 4 demonstrates that the source of trust based on family validation lowers anxiety.

Unexpected findings can also be interpreted with the help of this mechanism. One example is the insignificant effect of PC on ASM (H8). Qualitative evidence indicates that to certain people, especially those who have high Mianzi interests, the need to shun shame takes precedence over self-control. This implies that there is an intricate interaction amongst cultural appraisals.

To begin with, the model works best when the technology is based on the relationships within a family and social reputation. These are social communication sites such as WeChat. It can have a lower predictive validity on technologies utilised in the domain of individual privacy. Examples are individual gaming. Relational obligations (Xiao, Mianzi, Hexie) become less conspicuous in such a situation (Lynn-Sze & Yin, 2021).

Second, mechanisms can be identified most among older adults who are highly socialised by the traditional Confucian values. They have a more interdependent self-construal (Markus & Kitayama, 1991). Hybrid cultural schemas are becoming more and more developed by younger generations. They compromise between the social needs and individualistic wants of independence (Li et al., 2024).

Third, the applicability might not be similar in Confucian societies. They include South Korea, Japan, and Vietnam. Every society possesses its own historical-socio-economic background. These determine how the values of core are manifested and given precedence (Terpstra-Tong & Ralston, 2025). It is thus necessary to have cross-cultural validation.

In addition, the online data collection technique can have an inherent bias in the sample. It can give preference to the older generation that is already more digitally connected. The model can be tested regarding the strength of the model by using offline or multi-channel recruitment in future studies in various segments of the ageing population.

Theoretical Implications

We have three theoretical contributions. First, we redefine the concepts of meaningful goals in SST and the strategies in SOC as relational obligations (Xiao, Mianzi, Hexie) and not individual emotional tastes. Significant objectives in SST do not simply constitute those that are emotionally positive. Instead, they are social responsibilities which are culturally determined. Some of them are filial piety (Xiao), face (Mianzi), and harmony (Hexie). The ethical responsibilities can be met by using “ptimization and compensation in SOC. They do this without destroying harmony (Hexie).

Second, TAM, UTAUT, and other associated constructs still offer useful predictions of behaviour. Nevertheless, their meaning in everyday life and the relations which are behind them are largely influenced by the culture. The meaning of usefulness is transformed into familial usefulness. Social Influence changes to Mianzi-inspired moral concern. Behavioural Control is re-defined as personal mastery to relational governance. Importantly, we project this reconstruction to the affective realm. This is a culturally neutral area that is not taken seriously by mainstream models. We demonstrate that Enjoyment is also closely associated with relational fulfilment (Xiao).

Third, our integrative Confucian SST-SOC Model offers a process-oriented model that is testable. It explains the ways and reasons as to why culture dictates behaviour. Our model also makes a contribution to the field by establishing three sequential mechanisms. It goes beyond proposing that culture is important, to how culture influences the adoption of technology at later stages in life. It unveils the role of factors that are less evident but come under the skin to impact behaviour because of cultural aspects (Oyserman, 2017).

Practical Implications

The model is used to determine the specific cultural levers (Xiao, Hexie, Mianzi). These inform technology design and promotions. To developers, this implies the focus on functions that enable bonding of families. These are simplified groups of the family and one-touch video calls. It is also related to making sure that there is harmony in relation. Some of these are effective feedback to avoid misunderstanding and convenient undo to save face. Framing training is important to policymakers and educators who are developing digital literacy programs.

Limitations and Future Research

First, convenience sampling might not be entirely representative of the entire ageing population of China. This is especially for the people in remote rural places. A stratified random sampling should be used in future studies. They are expected to put more geographical and cultural contexts to the test. Some examples can be made of comparing China, South Korea and Japan.

Second, there is no causal conclusion due to the cross-sectional nature of the design. Longitudinal studies of the use of technology over time are imperative. They are required to know the way these cultural mechanisms interact.

Third, complex constructs are difficult to measure. It is supported by the modest reliability (CR = 0.66) of the ASM scale. This indicates how challenging it is to measure the culturally shaped finer behaviours using a small number of items. More elaborate culturally-grounded scales

should be created in the future. These need to be in a better position to distinguish the various motivational bases of avoidance.

Conclusion

The paper redefines the digital era of ageing with two paradigm shifts, namely, individual mastery to relational control, and universal metrics to culturally specific. Technology adaptation in Confucian cultures implies the process of intergenerational negotiation, that is, control is distributed among family members to maintain a sense of harmony, and avoidance is a relational ethics practice. The modest reliability of ASM (CR = 0.66) proves that individualistic measures are not sufficient to explain collective behaviours, which explains the necessity of culturally-sensitive measurement scales.

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Inclusive Kitchen Design for Older Adults: Generative AI Visualizations to Support Mild Cognitive Impairment

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Abstract

Mild Cognitive Impairment (MCI) affects 15–20% of adults aged 65 and older, often making kitchen navigation and independent living difficult, particularly in lower-income communities with limited access to professional design help. This study created an AI system that converts standard kitchen photos into MCI-friendly designs using the Home Design Guidelines (HDG). Stable Diffusion models, enhanced with DreamBooth LoRA and ControlNet, were trained on 100 kitchen images to produce realistic visualizations with open layouts, transparent cabinetry, better lighting, non-slip flooring, and less clutter. The models achieved moderate to high semantic alignment (normalized CLIP scores 0.69–0.79) and improved visual realism (GIQA scores 0.45–0.65). In a survey of 33 participants (51.5% caregivers, 36.4% older adults with MCI), the AI-modified kitchens were strongly preferred as more cognitively friendly (87.4% of 198 choices, $p < .001$). Participants reported high confidence in their kitchen choice selections ($M = 5.92/7$) and found the visualizations very helpful for home modifications ($M = 6.27/7$). Thematic analysis emphasized improved visibility, lower cognitive load, and greater independence. Overall, this AI tool provides a low-cost, scalable way for older adults and caregivers to visualize and implement DIY kitchen changes, supporting aging in place and resilience for those with MCI.

Keywords: mild cognitive impairment, generative artificial intelligence, stable diffusion, home design guidelines, aging in place, universal design

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Introduction

Mild Cognitive Impairment (MCI) involves a noticeable decline in cognitive functions, such as memory, attention, and visuospatial abilities, beyond typical age-related changes but not severe enough to qualify as dementia (Petersen et al., 2018). MCI affects an estimated 15–20% of adults aged 65 and older worldwide (Bai et al., 2022). Older adults with MCI often struggle with instrumental activities of daily living (IADLs), like meal preparation, financial management, and household maintenance, which are critical for maintaining independence (Jekel et al., 2015). These challenges are particularly evident in high-risk areas of the home, such as the kitchen, bathroom, and living spaces. The kitchen stands out as a vital space, linked to both activities of daily living (ADLs), such as eating, and IADLs, such as cooking, making it a key focus for interventions to support independent living (Lawton & Brody, 1969). Recent research further shows that specific home design factors significantly influence how older adults with MCI perform IADLs, underscoring the importance of evidence-based environmental modifications (Machry et al., 2025; Wahl et al., 2012).

Cognitive and functional declines associated with MCI often require modifications to the home environment to enhance safety, usability, and comfort. For example, visuospatial deficits can impair navigation and object recognition, while memory issues may make it hard to recall task sequences (Farias et al., 2006). Recent studies confirm that features such as open shelving significantly reduce cognitive load and improve task performance for older adults living with MCI (Bilau et al., 2025; Johansson et al., 2011). Universal design principles, which emphasize creating environments usable by people of all abilities, provide the overarching framework for such modifications (Sanford, 2012; Steinfeld & Maisel, 2012). To address these needs, Yang et al. (2023) developed the Home Design Guidelines (HDG), a comprehensive resource offering evidence-based design strategies and recommendations tailored for individuals with MCI and their caregivers. The HDG suggests modifications ranging from simple do-it-yourself changes, such as decluttering spaces, changing colors, adding labels, or improving lighting, to extensive renovations, such as reconfiguring layouts or integrating smart home technologies.

Despite its value, the HDG faces barriers to adoption, primarily due to the cognitive limitations of individuals with MCI. Research shows that people with MCI struggle to process complex textual information and benefit more from visual aids (Albert et al., 2011). Visual representations are often more intuitive, aiding comprehension and decision-making (Bourgeois, 1992). However, translating the HDG's textual recommendations into personalized visual designs typically requires professional architects or interior designers, which can be costly and time-consuming. This financial and logistical burden highlights the need for an innovative, accessible solution to bridge the gap between the HDG and its practical application.

Recent advancements in artificial intelligence (AI) offer a promising way forward. AI-driven image generation technologies, such as stable diffusion models, excel at creating realistic, contextually relevant images from text prompts or existing visuals (Rombach et al., 2022). By harnessing these tools, it may be possible to transform the HDG's recommendations into MCI-friendly visual renderings of home environments, reducing the cognitive strain on individuals with MCI and their caregivers. This study explores the use of stable diffusion models, enhanced by techniques like DreamBooth LoRA and ControlNet, to generate image-to-image transformations of existing kitchen interiors into MCI-friendly designs.

Stable diffusion is a latent diffusion model that produces high-quality images from text prompts or modifies existing images based on specific constraints (Rombach et al., 2022). Other models, such as DALL·E 2 (Ramesh et al., 2022) and VQ-VAE-2 (Razavi et al., 2019), were considered but deemed less suitable. DALL·E 2 lacks precision for fine-grained image modifications, and VQ-VAE-2 struggles with detailed architectural rendering. Within the stable diffusion framework, DreamBooth LoRA (Low-Rank Adaptation) supports fine-tuning pre-trained models on specific datasets for personalized image generation (Hu et al., 2021). ControlNet adds spatial control, ensuring accurate layout and object placement, which is ideal for architectural applications (Hattori et al., 2024; Zhang et al., 2023). These tools were chosen for their balance of flexibility, precision, and computational efficiency.

Given the wide range of possible home modifications, this study focuses on the kitchen, a critical space for independent living due to its role in ADLs and IADLs (Lawton & Brody, 1969). The research questions guiding this work are:

- **RQ1.** Can an AI model, specifically stable diffusion with DreamBooth LoRA and ControlNet, effectively generate MCI-friendly kitchen designs from existing kitchen images?
- **RQ2.** Do the generated images align with HDG recommendations for usability, safety, and accessibility when evaluated through semantic alignment with prompts and assessments of visual quality and realism?
- **RQ3.** To what extent do older adults with MCI and their caregivers perceive the AI-generated designs as more cognitively friendly, realistic, and helpful for planning home modifications?

To answer these questions, the study adopts a multi-phase approach: (1) data collection using HDG-derived prompts, (2) model training, (3) technical evaluation with CLIP and GIQA metrics, and (4) user validation through a survey with older adults with MCI and their caregivers.

This research aims to advance the intersection of AI and assistive technologies by offering a scalable, cost-effective solution to enhance independence and quality of life for individuals with MCI.

Methods

This study employed a mixed-methods design to develop and evaluate an AI-driven system capable of transforming standard kitchen images into MCI-friendly designs aligned with the evidence-based HDG. The methodology consisted of two main components: (1) development and technical evaluation of the generative AI model and (2) user validation through an online survey. All procedures were reviewed and approved by the Georgia Institute of Technology Institutional Review Board (IRB) as exempt research involving minimal risk. Electronic informed consent was obtained from all participants prior to data collection.

Phase 1: AI Model Development

A Python-based tool was developed to collect high-quality images of universal-design-friendly kitchens from Unsplash, a platform providing openly licensed stock photography. The Unsplash API was utilized for its reliability and simplicity. Approximately 100 images were gathered along with associated metadata describing design features. The permissive licensing of Unsplash ensured full legal compliance for research purposes. All images were preprocessed

by resizing to 512 × 512 pixels and normalizing pixel values, then manually annotated with HDG-derived text prompts, such as “open shelving,” “transparent cabinetry,” “non-slip flooring,” and “under-cabinet lighting.” The dataset was partitioned into training (80%), validation (10%), and test (10%) sets.

Phase 2: Model Training

Training was conducted on a single NVIDIA GeForce RTX 3080 GPU. Four progressive model variants (M1–M4) were developed using Stable Diffusion enhanced with DreamBooth Low-Rank Adaptation (LoRA) and ControlNet. Model M1 served as the baseline and was trained for 10,000 steps using HDG-focused prompts emphasizing open layouts and transparent cabinetry. Models, M2-M4, underwent additional fine-tuning for 15,000–20,000 steps, incorporating ControlNet’s Canny edge and depth conditioning to improve spatial coherence. A learning rate of 1 × 10^{-4}, a batch size of 4, and a 50% random replacement of prompts with empty strings were used to enhance robustness, following established practices (Zhang et al., 2023). Negative prompts such as “clutter” and “dark” were consistently used to prioritize accessibility-focused outputs.

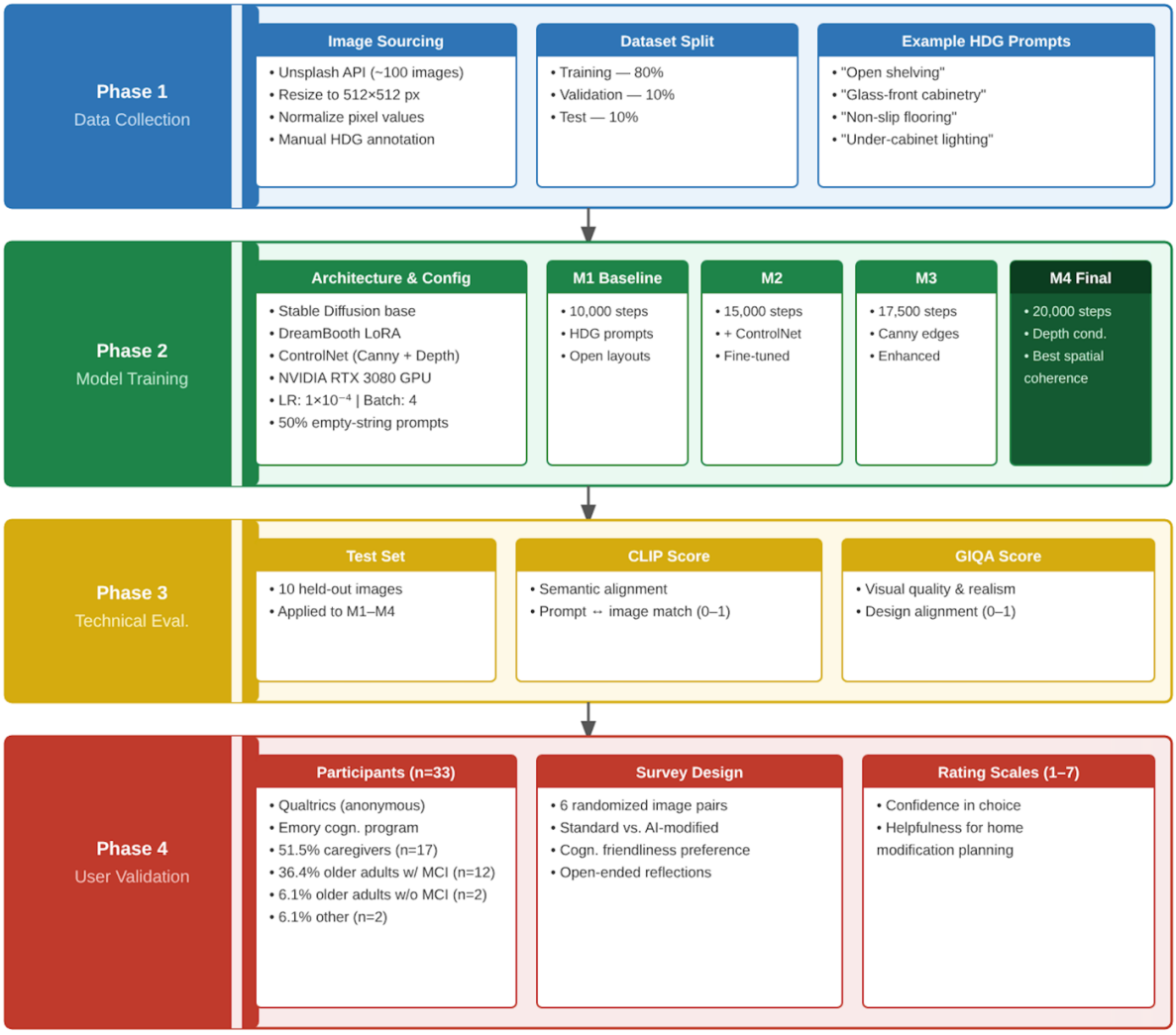
Phase 3: Technical Evaluation

Ten held-out test images were processed through each model. Generated outputs were evaluated using two established metrics: CLIP Score for semantic alignment between HDG prompts and the resulting images (Radford et al., 2021), and Generated Image Quality Assessment (GIQA) for visual quality and realism (Gu et al., 2020). These metrics were selected over alternatives such as Fréchet Inception Distance (Kynkäänniemi et al., 2019; Sajjadi et al., 2018) because they better capture functional design alignment rather than mere diversity. CLIP and GIQA scores were normalized to a 0–1 scale for interpretability.

Phase 4: User Validation Survey

To assess real-world acceptability, an anonymous online survey was administered via Qualtrics. Participants were recruited exclusively from members and alumni of a cognitive empowerment program at Emory University, a community-based initiative designed specifically for older adults living with MCI. The survey presented six randomized pairs of images (standard kitchen versus the corresponding AI-modified version). For each pair, participants selected which kitchen appeared more cognitively friendly (easier, safer, and more usable for someone with memory or attention difficulties), rated their confidence in the choice (1–7 scale), and indicated how helpful such visualizations would be for planning home modifications (1–7 scale). Open-ended explanations and general reflections were also collected. Thirty-three participants completed the survey: 17 caregivers or care partners (51.5%), 12 older adults with MCI (36.4%), 2 older adults without MCI (6.1%), and 2 others (6.1%).

Figure 1
Four-Step Methodological Framework: Data Collection, Model Training, Technical Evaluation, and User Validation



Results

This study evaluated the AI system through two complementary approaches: objective technical metrics on the generative models and direct user validation via a survey. Together, these analyses addressed all three research questions by confirming technical alignment with the HDG and strong real-world acceptability among older adults and caregivers.

AI Model Performance

Four progressive model variants (M1–M4) plus a baseline (M0) were tested on 10 held-out kitchen images. Semantic alignment with HDG prompts was measured using normalized CLIP scores (0–1 scale). Mean normalized scores showed a gradual decline from M1 (0.79) to M4 (0.69), while M0 averaged 0.67. Individual image scores ranged from approximately 0.16 to 1.00 (see Figure 2 and Table 1). Although raw CLIP means ranged from 30.93 for M1 to 29.57 for M4, this modest reduction reflects progressive specialization rather than degradation. Later models incorporated MCI-specific features such as transparent cabinetry, assistive elements, and reduced clutter, which are underrepresented in CLIP's general training data (Schuhmann

et al., 2022), resulting in deliberate divergence from generic kitchen imagery rather than a loss of semantic quality.

Visual realism and coherence were assessed using GIQA metrics. Normalized GMM scores (global realism) were highest for M1 at approximately 0.94 and declined progressively to approximately 0.58 for M4. Individual values ranged from approximately 0.08 to 1.00 (see Figure 3 and Table 2). Normalized KNN scores (local feature coherence) followed a similar pattern, with M1 at approximately 0.95 decreasing to approximately 0.32 for M4 (see Figure 4 and Table 3).

These patterns indicate that later models learned a coherent MCI-friendly design distribution distinct from standard kitchens. Average scores across metrics are summarized in Figure 5, and representative visual comparisons appear in Figure 6. Expert review confirmed that M2–M4 preserved spatial layout while clearly integrating open shelving, improved lighting, and non-slip flooring.

Although later models (M2–M4) produced outputs that were increasingly distinctive of MCI-friendly design, M1 consistently showed the strongest overall performance across CLIP, GMM, and KNN metrics, indicating that it was best across semantic alignment and visual realism, and was therefore selected as the final model. The six image pairs used in the user survey were generated with M1 applied to standard American kitchen photographs. Collectively, the metrics confirm that the models effectively generated HDG-aligned designs (RQ1 and RQ2), with M1 providing the optimal balance for real-world application.

Figure 2

Normalized CLIP Similarity Scores per Image

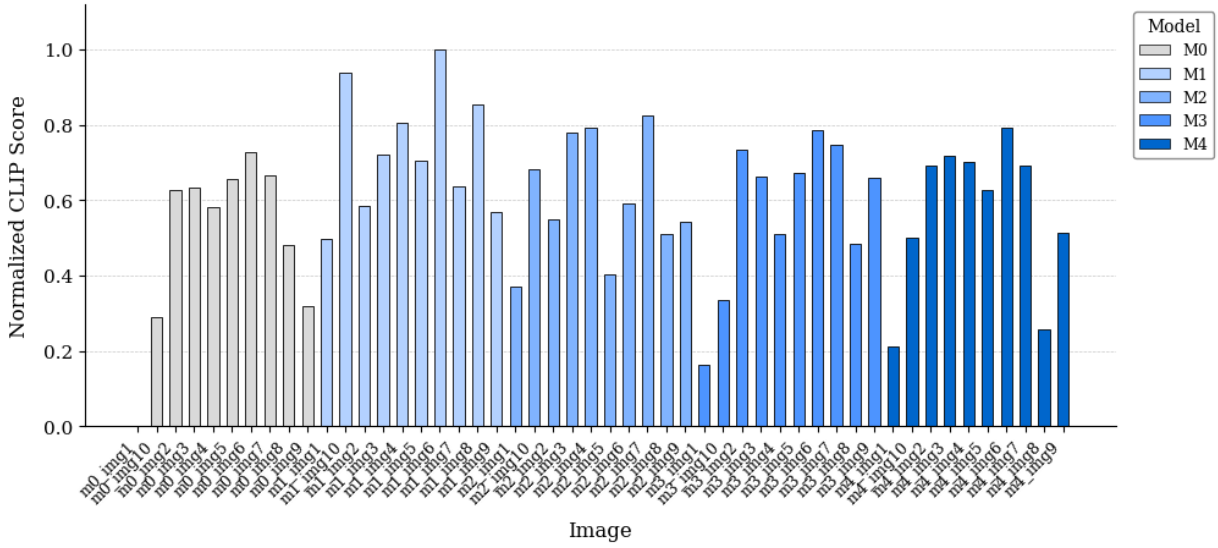


Table 1
CLIP Scores per Model. % Quality Relative to Best Model (M1-M4). Vs Input = % Change Relative to M0 Baseline

Model	Mean	% Quality	vs Input	Rank
M0	28.9447	—	—	—
M1	30.9256	100.0%	+6.8%	#1
M2	29.8510	96.5%	+3.1%	#2
M3	29.5998	95.7%	+2.3%	#3
M4	29.5652	95.6%	+2.1%	#4

Figure 3
Normalized GIQA GMM Scores per Image

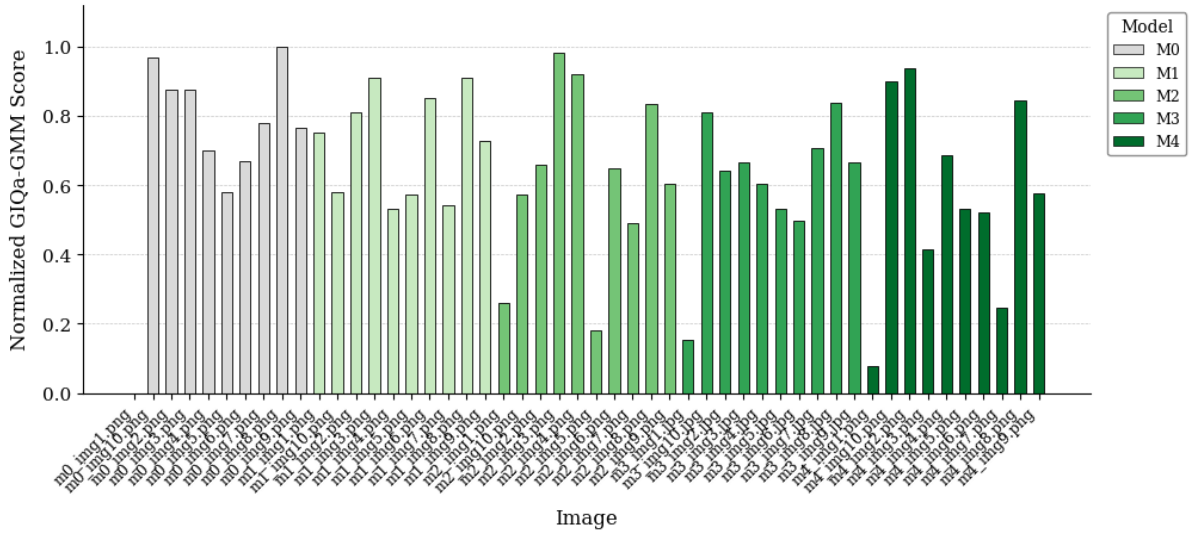


Table 2
Raw GIQA-GMM Log-Likelihood Scores per Model. % Quality Relative to Best Model (M1–M4). Vs Input = % Change Relative to M0 Baseline

Model	Mean	% Quality	vs Input	Rank
M0	-7,640,876.0659	—	—	—
M1	-7,668,629.0891	100.0%	-0.4%	#1
M2	-9,083,346.2760	84.4%	-18.9%	#2
M3	-9,135,986.5661	83.9%	-19.6%	#3
M4	-9,643,285.8763	79.5%	-26.2%	#4

Figure 4

Normalized GIQA KNN Scores per Image

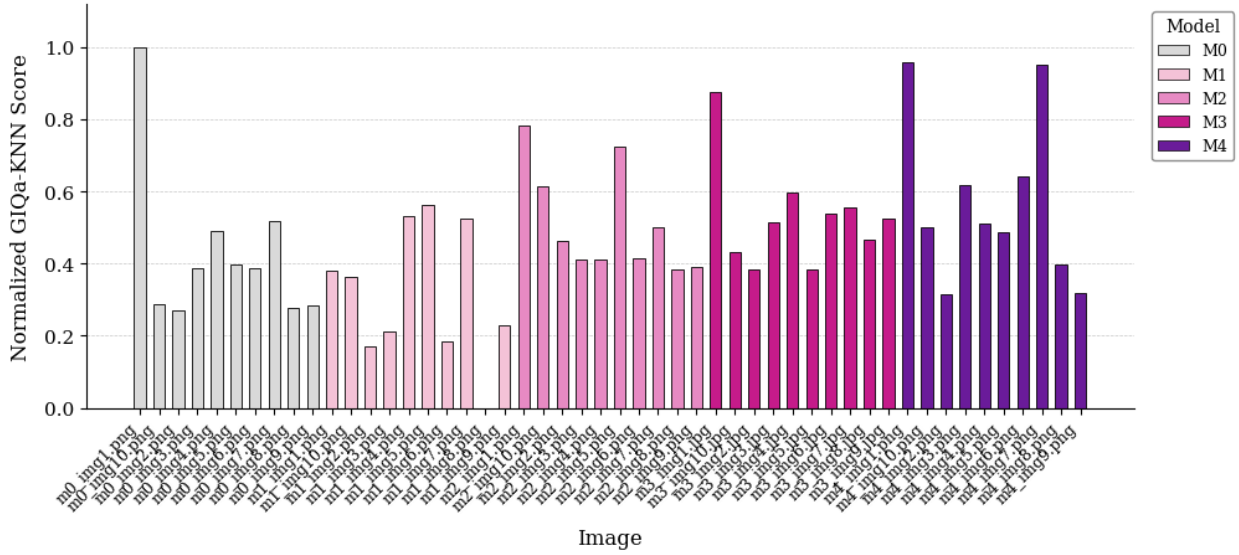


Table 3

Raw GIQA-KNN Log-Likelihood Scores per Model. % Quality Relative to Best Model (M1–M4). Vs Input = % Change Relative to M0 Baseline

Model	Mean	% Quality	vs Input	Rank
M0	9.3586	—	—	—
M1	8.8503	100.0%	+5.4%	#1
M2	9.7139	91.1%	-3.8%	#2
M3	9.7910	90.4%	-4.6%	#3
M4	9.9784	88.7%	-6.6%	#4

Figure 5

Average Normalized CLIP, GIQA-GMM, and GIQA-KNN Scores per Model

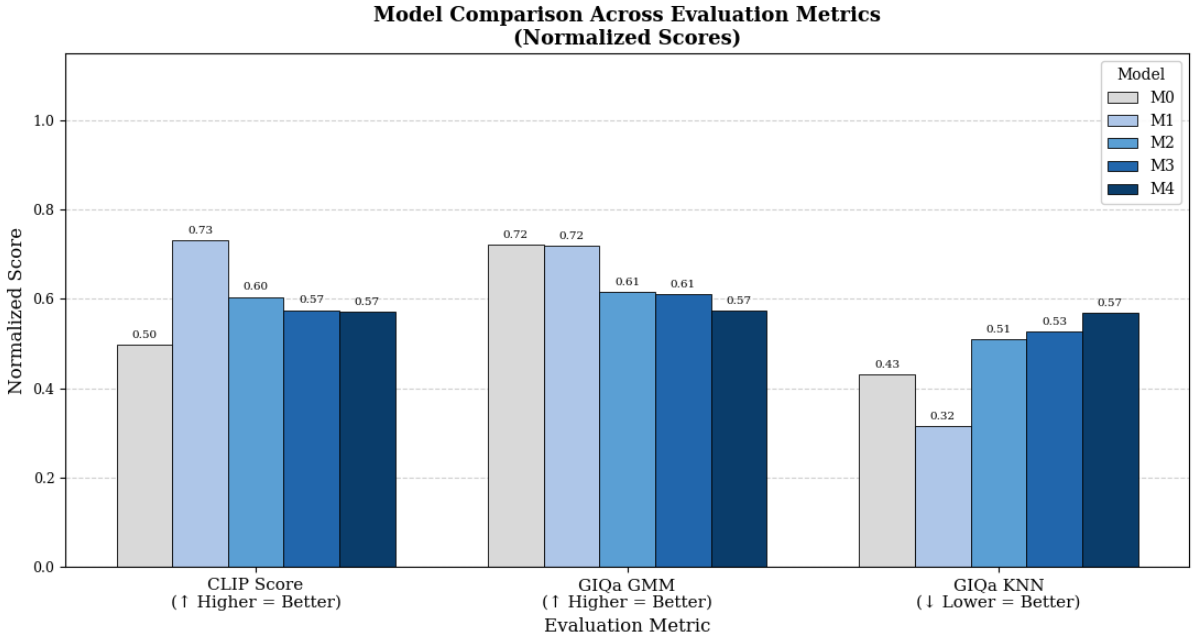
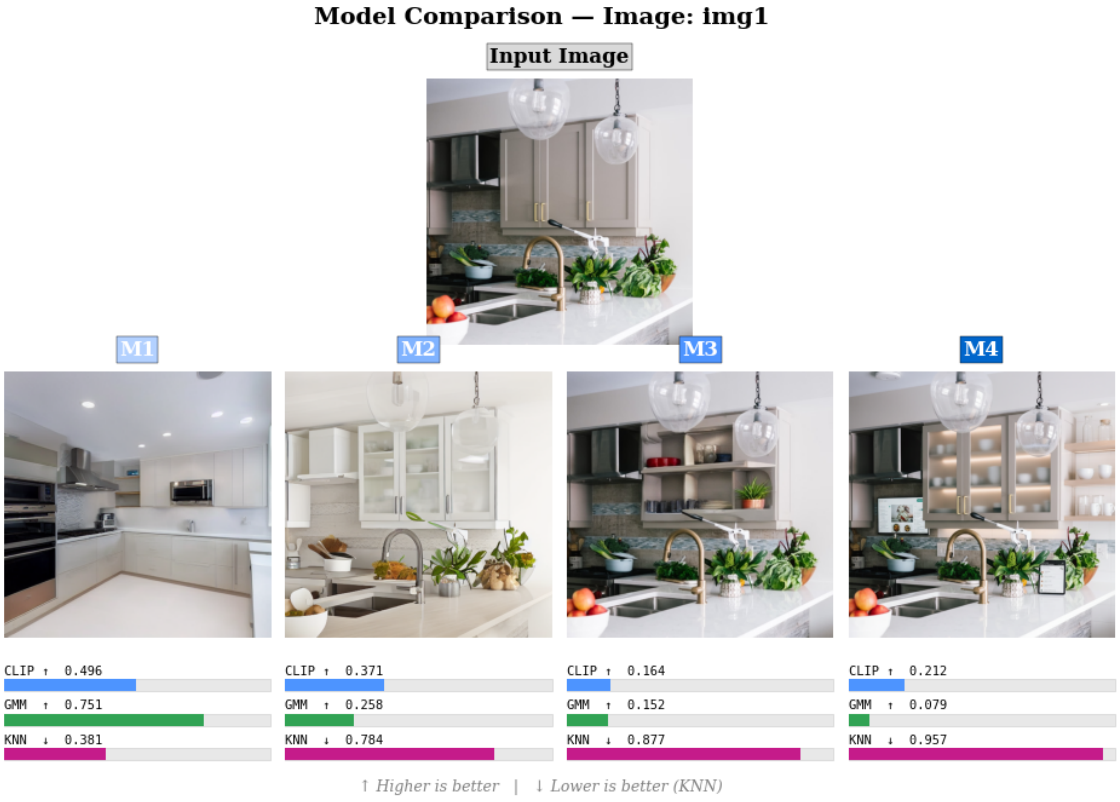


Figure 6

Visual and Quantitative Model Comparison per Model



User Validation Results

To assess real-world acceptability, an anonymous online survey was administered via the Qualtrics platform. Participants were recruited exclusively from members and alumni of a

cognitive empowerment program at Emory University. A total of 33 participants completed the survey. The sample was predominantly older adults (51.5%, n = 17, aged 70–79; 33.3%, n = 11, aged 80 or older; 12.1%, n = 4, aged 60–69; 3.0%, n = 1, aged 50–59), with 51.5% (n = 17) identifying as caregivers or care partners, 36.4% (n = 12) as older adults with MCI, 6.1% (n = 2) as older adults without MCI, and 6.1% (n = 2) as other. Most were highly engaged in kitchen activities (60.6% cooking daily, 24.2% frequently), aligning with the target population.

Participants viewed the six randomized image pairs generated by the selected M1 model (see Figure 7). For each pair, they selected which kitchen appeared more cognitively friendly (easier, safer, and more usable for memory or attention difficulties), rated their confidence in the choice (1 to 7 scale), and indicated how helpful such visualizations would be for planning home modifications (1 to 7 scale). Open-ended explanations and general reflections were also collected.

Of 198 total choices, 173 (87.4%) favored the AI-modified kitchens ($p < .001$ for each pair and overall; 95% CI [82.8%, 100%]).

Table 4
Preference for Optimized Kitchens by Image Pair (N = 33)

Image Pair	Percent Choosing Optimized	Successes	p-value (binomial one-sided)	95% CI
Pair 1	100 %	33	< .001	[89.4, 100]
Pair 2	79 %	26	< .001	[60.3, 91.3]
Pair 3	88 %	29	< .001	[71.8, 96.6]
Pair 4	91 %	30	< .001	[75.7, 98.1]
Pair 5	82 %	27	< .001	[64.5, 93.0]
Pair 6	85%	28	< .001	[67.5, 95.2]
Overall	87.4 %	173/198	< .001	[82.8, 100]

Confidence in choices was high ($M = 5.92$ out of 7 across pairs, $SD \approx 1.1$), significantly above the neutral midpoint of 4 (one-sample t-test, $p < .0001$). Perceived helpfulness of AI-generated visualizations for planning home modifications (Q7, 1 to 7 scale) was also strongly positive ($M = 5.7/7$), with 72.7% (n = 24) rating them as "Helpful" (6) or "Extremely Helpful" (7). Only two respondents (6.1%) rated the visualizations negatively. Subgroup analyses showed no statistically significant differences.

Thematic analysis of open-ended responses (Braun & Clarke, 2006) identified two primary themes.

The dominant positive theme, visibility and reduced cognitive load, which were mentioned in more than 80% of responses, centered on open shelving or transparent cabinetry *("Can see everything without opening doors and guessing"*), minimal clutter, enhanced lighting (under-

cabinet or kick-plate), and visual cues (labels, fridge notes, recipe tablets). Participants noted these features minimized memory search and distraction, directly supporting safer, more independent meal preparation and activities in the kitchen.

A secondary theme, practical concerns and realism (approximately 35 to 40% of responses), highlighted potential drawbacks of open shelving (reaching high shelves, risk of disorganization or dust in daily use), and loss of counter space. Many appreciated the designs for MCI but questioned long-term maintainability *("I love it for MCI, but I would not keep open shelves perfectly organized"*). Realism ratings were more mixed than preference scores, with several noting the optimized versions appeared "too perfect or sterile" for real homes.

Figure 7

Original and M1-Generated Cognitive-Friendly Versions of the Six Kitchen Images Used in the User Validation Survey

The combined technical and user evidence demonstrates that the AI system (particularly the best-performing M1 model) successfully generated MCI-friendly kitchen designs that align with HDG recommendations and are strongly preferred by the target population. These findings fully address all three research questions and establish the models as practical visual tools for accessible home modification.

Discussion

This study demonstrated that generative AI can effectively transform ordinary kitchen photographs into MCI-friendly designs aligned with the HDG. By combining technical model evaluation with direct feedback from 33 older adults and caregivers, the findings provide strong support for all three research questions and offer a practical pathway toward more accessible home modifications.

The AI models, particularly the best-performing M1 variant, successfully generated designs that incorporated key HDG features, including open layouts, transparent cabinetry, improved lighting, and reduced visual clutter. Although normalized CLIP scores showed a modest decline from earlier to later models, this pattern indicated successful specialization rather than reduced quality. Later models deliberately diverged from generic kitchen imagery to better represent MCI-specific accessibility elements that are underrepresented in standard training data. Similarly, GIQA metrics confirmed that the models maintained acceptable levels of visual realism while learning a coherent MCI-friendly aesthetic. These technical outcomes directly affirm that stable diffusion models enhanced with DreamBooth LoRA and ControlNet can generate functionally relevant designs (RQ1 and RQ2). Because M1 provided the optimal balance across all metrics, it was used to create the six image pairs evaluated by participants.
User validation provided even stronger evidence of real-world value. Participants

overwhelmingly preferred the M1-generated kitchens as more cognitively friendly (87.4% of choices), reported high confidence in their selections, and rated the visualizations as highly helpful for planning home modifications. Thematic analysis reinforced that open or glass-front shelving, reduced clutter, and enhanced lighting were the most valued features because they reduced memory demands and visual search time. These findings align closely with Bilau et al. (2025), who showed that visible storage measurably lowers cognitive load and improves task efficiency during meal preparation for people with MCI. The secondary theme of practical realism also echoes previous work highlighting the need for balanced designs that remain maintainable in daily life (Johansson et al., 2011).

The results have important practical implications. By enabling individuals and families to upload a photo of their existing kitchen and instantly see evidence-based modifications, this AI approach removes major barriers that previously limited the adoption of the HDG. This is especially valuable for lower-income households and those without access to professional designers. The high perceived helpfulness ratings suggest that such tools can empower older adults and caregivers to make simple do-it-yourself (DIY) changes that enhance safety, independence, and quality of life. These outcomes support the broader goal of aging in place and build resilience in the face of cognitive changes.

The study also contributes to the emerging literature on generative AI in accessible design. While previous work has explored AI for general residential layouts (Zhou & Pan, 2025), this research is among the first to combine technical development with direct validation from the MCI community. The strong user preference and clear thematic support extend earlier findings on environmental modifications that reduce fall risk and support IADLs (Dalvand et al., 2024; Gitlin et al., 2006; Jekel et al., 2015).

Overall, the integration of technical performance and user-centered validation demonstrates that AI-generated visualizations offer a scalable, low-cost solution to a long-standing challenge in cognitive accessibility. This approach bridges the gap between evidence-based guidelines and practical implementation, with meaningful potential to improve daily living for older adults with MCI and their care partners.

Limitations and Future Work

Although this study produced promising results, several limitations should be noted. The training dataset of approximately 100 images from Unsplash was modest and may not fully capture the diversity of real-world kitchens or cultural preferences in design. The technical metrics (CLIP and GIQA) are useful for semantic and visual assessment but do not measure actual functional performance in everyday use. In addition, while the survey with 33 participants from the Emory cognitive empowerment program provided valuable user validation, it relied on static image pairs rather than in-home trials or long-term experience with the modifications. The convenience sample was also predominantly U.S.-based and may limit generalizability across broader populations.

Future work will address these gaps in several ways. First, the training dataset will be expanded with more diverse kitchen images and transfer learning from larger architectural collections to improve cultural and stylistic coverage. Second, a user-friendly web interface can be developed so individuals with MCI and their caregivers can upload photos of their own kitchens and generate personalized modifications instantly. Third, longitudinal studies will track actual home changes and measure outcomes such as safety, independence, and caregiver burden.

Finally, the approach will be extended to other key living spaces, including bathrooms and entryways, to create a more comprehensive solution for aging in place.

Conclusion

This study demonstrates the power of generative artificial intelligence to translate the HDG into clear, actionable visual tools for people living with MCI. The models, especially the best-performing M1 version, successfully produced designs featuring open layouts, transparent cabinetry, improved lighting, and reduced clutter. Technical metrics confirmed strong alignment with HDG recommendations, while the survey of 33 older adults and caregivers showed overwhelming preference for the AI-modified kitchens (87.4%) and high ratings for helpfulness in planning modifications. Participants particularly valued the increased visibility and reduced cognitive load provided by open shelving and visual aids.

These findings directly address the research questions and offer a practical, low-cost solution that empowers families to visualize and implement simple DIY changes without professional assistance. By making evidence-based modifications easier to understand and adopt, this AI approach can enhance safety, independence, and quality of life for older adults with MCI. As the population ages, such accessible technologies will play a vital role in supporting cognitive health, reducing caregiver burden, and promoting resilient communities where people can age in place with dignity.

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Declaration of Generative AI and AI-Assisted Technologies in the Writing Process

The author declares that Grammarly, an AI-assisted writing software, was used in proofreading and refining the language used in the manuscript. The usage was limited to correcting grammatical and spelling errors and rephrasing statements for accuracy and clarity. The author also declares that Claude AI, a generative AI platform, was used in generating Figure 1 using content generated by the author. The author further declares that, apart from Grammarly and Claude AI, no other AI or AI-assisted technologies have been used to generate content in writing the manuscript. The ideas, design, procedures, findings, analyses, and discussion are originally written and derived from careful and systematic conduct of the research.

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Appendix

AI Kitchen Design Survey – MCI

Informed Consent

You are being asked to be a volunteer in a research study. The purpose of this study is to explore how artificial intelligence (AI) can generate home design images, particularly kitchens that support the needs of individuals with Mild Cognitive Impairment (MCI). By understanding how people perceive and evaluate different AI-generated kitchen layouts in terms of preference and realism, your responses will help refine the AI model to create more accessible and user-friendly designs.

The online survey will take approximately 10–15 minutes to complete. Responses will be kept confidential, anonymous (no identifiers collected), and used solely for academic research reported in aggregate form; we will comply with any applicable laws and regulations regarding confidentiality. The risks involved are no greater than those involved in daily activities. You will not benefit or be compensated for joining this study.

To make sure that this research is being carried out in the proper way, the Georgia Institute of Technology IRB may review study records. The Office of Human Research Protections may also look at study records. If you have any questions about the study, you may contact Ibrahim Bilau at (850) 345-3488 or ibilau3@gatech.edu. If you have any questions about your rights as a research subject, you may contact Georgia Institute of Technology Office of Research Integrity Assurance at IRB@gatech.edu.

Thank you for participating in this study.

Consent Confirmation: Please confirm the following before proceeding.

○ I voluntarily agree to participate in this study.
○ I understand I can withdraw at any time without penalty.

By completing the online survey, you indicate your consent to be in the study. Your participation is entirely voluntary, and you may choose to skip any question or withdraw from the survey at any time.

Kitchen Comparisons

Q1 Please look at the two kitchens below. Which kitchen looks more cognitively friendly, i.e., easier to understand, safer, and easier to use for memory or attention difficulties?

Kitchen Image A	Kitchen Image B
[Image A]	[Image B]

○ Kitchen Image A
○ Kitchen Image B

Q2 How confident are you in your choice of the kitchen Image above?

1 = Not confident at all	2 = Slightly confident	3 = Somewhat confident	4 = Moderately confident	5 = Mostly confident	6 = Very confident	7 = Extremely confident
○	○	○	○	○	○	○

Q3 In one sentence, what made the kitchen you chose easier or safer to use for memory or attention difficulties?

Q4 Which kitchen looks more like a real home kitchen you might implement?

- ○ Image A looks much more realistic
- ○ Both look equally realistic
- ○ Image B looks much more realistic

Post Comparison

Q5 How helpful do you think AI-generated kitchen visualizations would be for planning home modifications?

1 = Not at all helpful	2 = Not helpful	3 = Slightly unhelpful	4 = Neutral	5 = Slightly helpful	6 = Helpful	7 = Extremely helpful
○	○	○	○	○	○	○

Q6 Please briefly explain any general thoughts about the kitchens or features that made them easier or harder to use.

Familiarity and Demographics

Q7 How often do you cook or help in the kitchen?

- ○ Every day
- ○ A few times a week
- ○ Occasionally
- ○ Rarely

Q8 What is your age group?

- ○ 50–64
- ○ 65–74
- ○ 75+

Q9 What is your relationship to MCI?

○ Older adult with MCI
○ Older adult without MCI
○ Caregiver/partner
○ Other

End of Survey

Thank you for participating! Your responses will help improve the design of safer, more accessible kitchens for older adults and caregivers.

Healthy Aging Activity as a Protective Factor Against Depression Among Community-Dwelling Older Adults in Rural Areas: A Scoping Review

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Abstract

Healthy aging activities, including physical, social, cognitive, and recreational, have been shown to have a protective effect on depression in older adults. However, little is known about how these activities function in rural areas. Therefore, the main objective of this scoping review is to systematically map existing research on healthy aging activities and their association with depression among older adults. A scoping review was performed on studies retrieved from databases such as Google Scholar, Embase, CINAHL, and PubMed published from 2015 to 2025. The researchers used Arksey and O'Malley's framework and the PRISMA-ScR checklist. Inclusion criteria were studies examining the connection between depression and activity engagement, rural populations, and older adults (≥ 60 years old) living in the community. Out of 2,400, only five articles satisfied the inclusion requirements. The results consistently showed that older adults who participated in family, social interaction, outdoor activities, physical exercise, and religion had fewer depression symptoms. Furthermore, it was discovered that socially integrated and structured activities were more protective than solitary or self-directed exercise, and that engaging in various activity domains improved mental health over time. Overall, the findings emphasized that healthy ageing activities, especially those that are varied and socially embedded, act as protective factors against depression among community-dwelling older adults. The results highlight the need to create community initiatives that support socially integrated and easily accessible activities for the elderly, particularly in rural communities.

Keywords: healthy aging activity, depression, older adults, scoping review

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Introduction

The aging population has been observed in many countries worldwide (Colby & Ortman, 2014; World Health Organization, 2019). According to WHO (2024), in 2020, people aged 60 and older outnumbered children younger than 5 years old. The age of 60 or 65, roughly equivalent to retirement, is considered the start of old age. As the aging population increases, several studies worldwide have focused on the physical health of older adults, such as disease prevention strategies (Aguilar-Navarro et al., 2025; Mahmud et al., 2025; Tohit & Haque, 2024) and promoting overall well-being and mental health that would help this vulnerable population achieve healthy aging (Espinosa, 2023).

Aging is accompanied by multidimensional changes in health, financial security, and social relationships that significantly influence psychological well-being. In particular, depression is one of the most common mental health problems among older adults worldwide, with estimates suggesting that 10–20% of community-dwelling older adults experience clinically significant depressive symptoms (Fiske et al., 2009). In the Philippines, for instance, depression in later life is under-recognized and often masked by somatic complaints, making it a hidden yet urgent public health concern (Espinosa, 2023).

Moreover, research highlights the importance of protective psychological mechanisms such as healthy aging activity (Faronbi et al., 2024; Umegaki et al., 2021) in buffering against depression. Aging is a period of both growth and decline (Baltes & Carstensen, 2003). Growth indicates that aging is a period for a more robust life meaning and purpose as the elderly reflect on their lives (Mamauag, 2019), making meaningful contributions to the community (Aalto et al., 2023), as well as having meaningful relationships with others (Pangandaman et al., 2021). Thus, older adults contribute to society as family and community members; many are volunteers and workers at the church.

However, aging is also a period of decline (De la Vega et al., 2021), often accompanied by transitions such as retirement, loss of loved ones, reduced social roles, and declining health and functional abilities (Hong et al., 2023). These aging-related phenomena can challenge an older adults' sense of purpose (Erikson, 1963; Yemiscigil et al., 2021) and social connectedness (Schmidt et al., 2022), and put them at risk of isolation and loneliness (Blazer, 2020), affecting their mental health and may lead to negative beliefs about self-worth, usefulness, and the future (Fu & Zhang, 2024). Therefore, mental health issues, such as depression, among older adults have become prominent (Gao et al., 2024). According to the Institute of Health Metrics and Evaluation (2023), around 14% of adults aged 60 and over live with a mental disorder. WHO (2017) estimated that the overall prevalence of depression among older adults aged 55 to 74 was from 5.5% to 7.5% of the global population in 2015. Thus, empirical studies are needed to address the rising concern of depression among the elderly to help them achieve successful aging (Kim et al., 2020).

Literature Review

Depression is one of the most prevalent mental health concerns among older adults and is often underdiagnosed and undertreated, particularly in rural settings where access to mental health services may be limited (World Health Organization, 2021). Community-dwelling older adults in rural areas are especially vulnerable due to factors such as social isolation, physical health decline, and lack of community infrastructure (Flores et al., 2018). While pharmacological treatments are available, non-pharmacological approaches, including

meaningful activity engagement, have gained increasing attention for their potential in promoting mental health and preventing depression in later life (Gao et al., 2024).

Activity engagement encompasses a broad range of behaviors that can be classified into physical, social, cognitive, spiritual, and civic domains. Numerous studies have documented the benefits of physical activities such as walking and gardening (Salt et al., 2017), as well as the positive effects of social participation and cognitive stimulation on psychological well-being (Choi et al., 2025). Religious or spiritual practices and civic involvement have also been linked to enhanced life satisfaction and reduced depressive symptoms (Brečka et al., 2024). However, despite the growing body of evidence supporting the mental health benefits of these activities, much of the existing literature has focused on urban or institutionalized populations, often overlooking the distinct experiences of older adults residing in rural communities.

Moreover, existing reviews have primarily examined activity engagement in general aging populations without disaggregating data based on setting or mental health outcomes. As such, there remains a significant gap in the literature concerning how different types of activity engagement influence depression specifically among community-dwelling older adults in rural areas. The contextual and cultural uniqueness of rural communities, including resource limitations and traditional social structures, necessitates a more targeted examination of this relationship. This scoping review aims to map the existing literature on the influence of activity engagement on depression among community-dwelling older adults in rural communities. By identifying the types of activities studied, their outcomes, and research gaps, the review seeks to inform future interventions, policy development, and culturally sensitive strategies for supporting mental health in aging rural populations.

Methods

Study Design

A scoping review outlined by Arksey and O'malley (2005) was used, which consisted of five steps: (1) identifying the research question, (2) identifying relevant studies, (3) study selection, (4) charting the data, and (5) collating, summarizing and reporting the results.

Search Methods

Studies retrieved from databases such as Google Scholar, Embase, CINAHL, and PubMed published from 2015 to 2025. The study used the PRISMA-ScR checklist. Inclusion criteria were studies examining the connection between depression and activity engagement, rural populations, and older adults (≥ 60 years old) living in the community, and studies written in English language were included. Empirical studies (quantitative, qualitative, and mixed-methods). Out of 2,400, only five articles satisfied the inclusion requirements.

Information Sources and Search Strategy

Electronic databases searched include Google Scholar, Embase, CINAHL, and PubMed published from 2015 to 2025. The search strategy used a combination of keywords and Boolean operators. An example for PubMed is as follows:

("healthy aging" OR "active aging" OR "successful aging" OR "activity engagement" OR "leisure activity" OR "physical activity" OR exercise OR "social participation" OR "cognitive activity" OR "hobbies" OR "meaningful activity") AND (depression OR "depressive symptoms" OR "mental health" OR "psychological distress") AND ("older adults" OR elderly OR seniors OR "aging population" OR "aged 60+" OR geriatric OR "community-dwelling older adults") AND (rural OR countryside OR "non-urban" OR "remote area" OR "village community")

Screening

Screening processes were done by all the authors ensuring that all the inclusion criteria were strictly followed.

Data Extraction

The data extraction was done using a table consisting of the author's name, year, country, study design, sample, activity type, depression measure, and key findings.

Data Analysis

The data were analyzed based on the Arksey and O'Malley (2005) guideline in line with the objective of this review to identify the types of activity and the effect of the healthy aging activity to depression among community-dwelling older adults in rural areas.

Results

Search Results

Figure 1
Prisma Diagram – Search Results

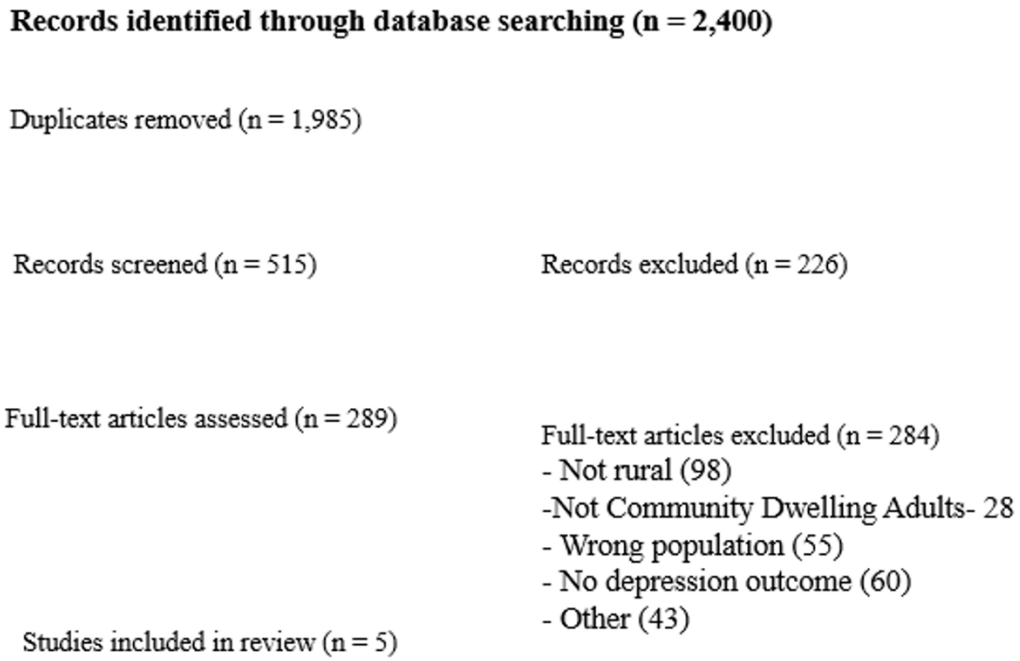

Table 1
Articles' Characteristics

Author, Year of Publication, &Title	Country	Study Design	Sample (n, age)	Activity Type	Depression Measure	Key Findings
Naveen et al. (2020) "Adding Life to years: Role of Gender and Social and Family engagement in geriatric depression in rural areas of Northern India"	India	Cross-sectional survey	n = 411, 60–69 yrs	Social and Family engagement	GDS-15	Older adults who maintain active participation in family life and social activities are less likely to experience depressive symptoms compared to those who are socially isolated or lack close family ties.
Lu et al. (2024) "Association Between Depression Status and Hearing loss among older adults: the role of Outdoor activity Engagement"	China	Longitudinal Healthy Longevity Survey	n = 12,333, ≥ 60 yrs	Tai Chi, square dancing, socializing with friends, and other outdoor pursuits	CESD-10	Outdoor activity engagement functions as a moderator by mitigating the psychological burden of hearing loss. Those who remain physically active and socially engaged in outdoor settings experience lower risks of depression.
Han et al. (2023) "Association between specific social activities and depressive symptoms among older adults: A study of urban-rural differences in China"	China	Cross-sectional survey	n = 20,813, ≥ 60 yrs	Social Activity	CESD-10	Engagement in social activities significantly reduces the risk of depression among older adults.

Author, Year of Publication, &Title	Country	Study Design	Sample (n, age)	Activity Type	Depression Measure	Key Findings
Ramalho et al. (2024) "On the move: A cross-sectional study on physical activity, sedentary behavior, and depressive symptoms among older people in rural Portugal"	Portugal	Cross-sectional	n = 54, ≥ 60 yrs	Physical Activity	Geriatric Depression Scale-27	Older adults who exercised on their own, without external guidance or structure, reported *more* depressive symptoms. Not all physical activity is equally beneficial for mental health. While self-directed exercise may not protect against depressive symptoms and may even be linked with higher distress structured, socially integrated physical activity appears to have a more robust protective effect on older adults' psychological well-being.
Roh et al. (2015) "Participation in physical, social, and religious activity and risk of depression in the elderly: a community-based three-year longitudinal study in	Korea	Longitudinal Study	n = 6,647, ≥ 60 yrs	Physical, Social, and Religious Activity	Geriatric Depression Scale-15 (Korean Version)	Participation in physical, social, and religious activity was associated with decreased risk of depression in the elderly. In addition, risk of depression was much lower in the elderly people who participated in two or three of

Author, Year of Publication, &Title	Country	Study Design	Sample (n, age)	Activity Type	Depression Measure	Key Findings
Korea”						the above-mentioned types of activity than that in the elderly who did not.

Discussion

The results consistently showed that older adults who participated in family, social interaction, outdoor activities, physical exercise, and religion had fewer depression symptoms. Furthermore, it was discovered that socially integrated and structured activities were more protective than solitary or self-directed exercise, and that engaging in various activity domains improved mental health over time. Overall, the findings emphasized that healthy ageing activities, especially those that are varied and socially embedded, act as protective factors against depression among community-dwelling older adults. The results highlight the need to create community initiatives that support socially integrated and easily accessible activities for the elderly, particularly in the Philippines.

As empirical studies documented, aging is a time for diminishing activity engagement. However, Havighurst’s activity theory of aging (1952) emphasizes that the loss of some roles and usual activities due to aging must be replaced by new activities to sustain well-being. According to Aalto et al. (2023), maintaining a socially active lifestyle and participating in meaningful activities are ways to contribute to society among the elderly. Further, when older adults feel they contribute to the community, they develop a high sense of life purpose, which contributes positively to their well-being (Tan et al., 2024). Schmitter-Edgecombe et al. (2017) healthy aging activity indicates healthy lifestyle behaviors such as biophysical activities, cognitive and social engagement, and health safeguard behaviors. Therefore, they treat healthy aging as a holistic form of engagement to achieve healthy well-being and avoid the development of mental issues such as depression among the elderly (Schmitter-Edgecombe et al., 2019). Yen et al. (2023) documented that frequent participation in physical and social activities is significantly associated with improved mental health outcomes, including increased happiness, life satisfaction, self-rated health, and decreased levels of depression. Activities like leisure and other social activities enhance older adults' mental health, leading to a good quality of Life (Aalto et al., 2023; Lamar et al., 2022). Therefore, healthy aging activities must continue to achieve good mental health

Conclusion

Based on the findings, the following conclusions were drawn. Firstly, older adults who participated in family, social interaction, outdoor activities, physical exercise, and religion had fewer depression symptoms. Secondly, socially integrated and structured activities were more protective than solitary or self-directed exercise, and that engaging in various activity domains improved mental health over time. And finally, healthy aging activities, especially those that are varied and socially embedded, act as protective factors against depression among community-dwelling older adults.

Declaration of Generative AI and AI-Assisted Technologies in the Writing Process

During the preparation of this work, the authors used ChatGPT to proofread the manuscript. After using this tool/service, the author(s) reviewed and edited the content as needed and take(s) full responsibility for the content of the publication. Also, the authors used Boolean operator generators for the purposes of data search. The authors have reviewed and edited the output and take full responsibility for the content of this publication.

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A Pilot Study on Fall Risk Assessment-Based Support for Fall Prevention Training

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Abstract

Falls among older adults are a leading cause of the onset of long-term care needs and represent a critical issue in medical and nursing fields. Because falls frequently lead to fractures, hospitalization, and increased need for long-term care, fall prevention is essential for maintaining the quality of life (QOL) of elderly individuals. A joint statement by ten Japanese medical organizations has noted that fall risk cannot be eliminated through operational processes alone, underscoring the need for a framework that identifies fall risk in advance and connects that assessment to targeted preventive intervention. This paper presents a pilot study that aims to develop such a framework by combining three components: (1) a survey of existing fall risk assessment methods, (2) a tablet-based questionnaire application for efficient data collection in clinical settings, and (3) a data analysis method based on logistic regression for estimating fall probability from questionnaire responses. The application supports two operational modes—self-assessment by patients and staff-assisted assessment—and is deployed across multiple hospitals with per-institution data isolation. Pilot deployments at two partner hospitals successfully collected questionnaire responses from several dozen patients and confirmed the practical feasibility of the proposed system. The resulting framework is designed to realize a closed loop of assessment, feedback, and prevention. Remaining challenges include increasing the volume of collected data, improving the accuracy of the analysis model, and investigating mechanisms to feed analytic results back to users in a manner that promotes sustained fall-prevention behavior.

Keywords: fall risk assessment, fall prevention, elderly care, questionnaire application, clinical prediction model

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Introduction

Population aging has made falls among older adults one of the most pressing concerns in contemporary health care and long-term care. Globally, falls account for an estimated 684,000 deaths each year and more than 170 million disability-associated fall injuries, a burden that has grown faster than that of most other injury categories (World Health Organization, 2021). Falls frequently trigger a sequence of adverse outcomes including fractures, prolonged hospitalization, loss of mobility, and a transition to a higher level of long-term care (Tinetti et al., 1988). In Japan, falls are repeatedly cited among the leading proximate causes of the onset of nursing-care certification, and the associated burden extends beyond the individual to families, medical institutions, and the social insurance system. For this reason, preventing falls is widely regarded as a key element in maintaining the quality of life of older adults.

Despite decades of research, however, fall prevention remains difficult in practice. A joint statement issued by ten Japanese medical organizations observes that fall risk cannot be eliminated by operational or procedural measures alone. This position reflects clinical reality: falls arise from the interaction of intrinsic factors such as aging, medication, cognition, and gait instability with extrinsic factors such as flooring, footwear, and the physical layout of the living environment (Tinetti et al., 1988). Because it is unrealistic to remove all such factors, it is important to identify those patients who are at elevated risk in advance and to provide them with preventive interventions tailored to the specific factors that apply to them (Ganz et al., 2007; Montero-Odasso et al., 2022).

This paper presents a pilot study that aims to develop a support system for fall prevention training that is grounded in quantitative fall risk assessment. The overall goal is to build a framework in which fall risk is first assessed, then fed back to the individual (and to caregivers), and then connected to concrete preventive action. To make this realistic in clinical settings, the study is organized around three interacting components: (1) a survey of existing methods for fall risk data collection and analysis, (2) a tablet-based questionnaire application that can be used by both patients and staff in real wards and outpatient clinics, and (3) a data analysis method that estimates fall probability from the collected responses.

The remainder of this paper is structured as follows. The next section reviews existing methods for fall risk assessment, including data collection modalities, time-series analysis techniques, and commonly used risk indicators. We then describe the design and implementation of the questionnaire application, followed by the logistic-regression-based analysis method. We report on the pilot deployment at two partner hospitals, and conclude with a discussion of limitations and future challenges.

Literature Review

Fall Risk Assessment Methods

A wide range of methods for fall risk assessment have been proposed and investigated, and recent global guidelines have attempted to synthesize them for routine practice (Montero-Odasso et al., 2022). At the data-collection layer, three broad modalities dominate the literature: wearable sensors, gait measurement, and questionnaire-based interviews. On the analysis layer, the collected data are mapped to risk indicators that may include gait parameters, biosignals, and statistical or machine-learning models.

Each modality has a characteristic balance of advantages and costs. Wearable sensors, such as inertial measurement units attached to the trunk or lower limbs, can yield high-resolution, objective measurements but require the subject to wear the device correctly and consistently, which is a nontrivial requirement in clinical populations that include frail or cognitively impaired individuals. Instrumented gait analysis produces objective parameters such as cadence, stride length, and gait variability, but depends on dedicated equipment and a controlled walking path, making routine deployment in busy wards difficult. Questionnaire-based approaches, by contrast, are simple to deploy and scale, and they can capture contextual information that is invisible to sensors, but their responses are inherently subjective.

Given these trade-offs, a practical fall risk assessment method for day-to-day clinical use should minimize the operational burden on staff and patients while still producing data that can support a quantitative risk model. Questionnaire-based methods are particularly attractive in this respect, provided that the instrument is well designed and that the collection process can be supported by appropriate digital tools.

Time-Series Data Analysis Methods

Falls are temporally distributed events rather than point-in-time outcomes, so time-series-aware analysis is an important consideration when designing a fall risk model. Two families of methods are particularly relevant.

Proportional hazards models, most notably the Cox model (Cox, 1972), explicitly represent the time until fall occurrence and allow the influence of multiple covariates—such as aging, medication, and exercise habits—to be estimated jointly. This makes them well suited to longitudinal cohorts in which follow-up times differ across participants.

Bayesian networks offer a complementary perspective (Pearl, 1988). By probabilistically representing the dependency structure between risk factors and fall events, they can express how interventions on a given factor (for example, increasing daily step count or modifying medication) propagate through to the probability of a fall. This makes them appealing for clinical decision support, where the question is not only “what is the current risk” but also “what can we change to reduce it.”

Fall Risk Indicators

A number of indicators have been proposed as quantitative proxies for fall risk. Gait parameters—cadence, stride length, and gait variability in particular—are widely used because they can be extracted from either instrumented gait laboratories or wearable sensors and because they correlate with the underlying motor control mechanisms implicated in falls. More recently, the maximum Lyapunov exponent, a measure of local dynamic stability of the gait cycle estimated via techniques such as that of Rosenstein et al. (1993), was proposed as an indicator that captures gait instability in a way that simpler aggregate measures do not.

These indicators are powerful, but most of them presuppose sensor-based or laboratory-based measurement. For questionnaire-driven pipelines, the equivalent role is played by composite scores computed from self-reported items such as history of prior falls, fear of falling, use of assistive devices, and activity level. In this study we focus on the latter class of indicators, because they align with our broader goal of enabling deployment in ordinary clinical settings.

Research Objectives

The overall objective of this research is to build a support system that assesses fall risk in older adults and connects that assessment to concrete fall-prevention actions. To make this objective tractable, it is decomposed into three sub-objectives.

First, we survey existing data collection and analysis methods for fall risk assessment, and identify methods and indicators that are both effective and compatible with routine clinical deployment. Second, we develop a fall risk analysis method that produces a quantitative probability of a future fall from the collected data. Third, we develop a questionnaire application that enables efficient data collection in clinical environments including wards and outpatient clinics.

The novelty of this research lies in the combination of these three components. Rather than relying solely on sensor-rich instrumentation, we place a questionnaire-centered risk assessment at the core of the system. Data are collected via tablet-based devices that can be operated by either patients or staff; items can be mapped or augmented using natural language processing techniques; and the resulting model is designed to be feasible even with the relatively small datasets that are realistically available from a single-hospital or small-consortium deployment.

Methodology

Overall Research Structure

The research proceeds along three mutually reinforcing lines: the survey of data collection and analysis methods, the development of the questionnaire application, and the design of the data analysis method. Together these define the closed loop that the system is designed to implement: risk assessment, feedback to the patient and caregiver, and preventive action informed by that feedback.

Survey of Data Collection and Analysis Methods

The first methodological step was a targeted literature review organized around three perspectives: time-series data analysis methods, data collection methods, and fall risk indicators. For each perspective we catalogued representative methods, summarized their operational requirements (for example, whether they require a wearable device, a dedicated walking path, or a specialized clinician), and noted their typical output format.

This survey served two purposes. First, it provided a rationale for the design choices in the questionnaire application: for instance, the decision to adopt a simple tablet-administered questionnaire rather than a sensor-heavy pipeline was informed by the practical constraints of ward deployment that the literature review surfaced. Second, the survey defined the space of analytic techniques that could be applied downstream, including the logistic regression model adopted here and the proportional-hazards and Bayesian-network approaches identified as promising directions for future work.

Questionnaire App Development

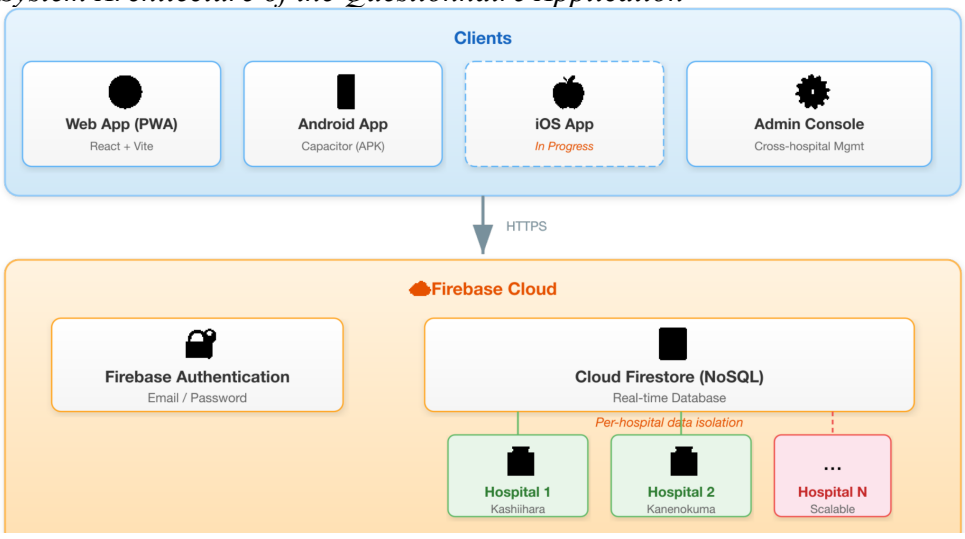
To reduce the manual effort associated with paper-based surveys and to enable consistent, multi-site data collection, we developed a tablet-based questionnaire application. The application was designed around the following requirements: it must run on commodity Android tablets that can be procured and maintained by partner hospitals; it must be usable by older adults, including those with limited prior experience of touch interfaces; it must protect the independence of each hospital's data; and it must produce structured data suitable for subsequent statistical analysis.

The resulting application delivers the twenty-one-item fall risk index developed by Toba et al. (2005) through large, touch-friendly controls. This index, also known as the FRI-21, consists of self-reportable items covering physical function, cognition, sensory and locomotive organs, medication, and environmental factors, and was validated as a predictor of future falls in community-dwelling older adults. The present implementation adopts this item set as the substantive basis of the instrument without modification; the contribution of the present work lies in delivering the questionnaire through a tablet-based application suitable for multi-hospital deployment rather than in redesigning the items themselves. Items are presented either as yes/no questions (Figure 2, center) or as multiple-choice questions (Figure 2, right), and the interface was tuned for elderly users, including generous touch targets and simple visual affordances. The application is cross-platform, available as a Progressive Web App and as an Android APK built via Capacitor, with iOS support under development. The user-facing text is in Japanese, reflecting deployment at Japanese partner hospitals.

Data management is performed via Firebase Firestore, with an architecture that ensures per-hospital data isolation: each hospital receives its own instance with its own branding, and patient data are scoped to that instance (Figure 1). An administrative console allows researchers to review deployments and to export survey results as CSV files for downstream analysis. Because the underlying codebase is shared, new features and fixes can be rolled out across all hospitals from a single source, while the deployed instances remain logically distinct.

Figure 1

System Architecture of the Questionnaire Application



Two Survey Modes

A distinctive feature of the application is that it supports two complementary survey modes. In Mode A (patient self-assessment), the patient answers directly on the tablet using their own account; this mode is intended for outpatients with sufficient cognitive ability and is designed around an intuitive touch-based UI. In Mode B (staff-assisted assessment), a staff member conducts the survey on behalf of the patient, selecting a registered patient from a list and then recording the patient's responses (Figure 2, left); this mode supports inpatients and patients with limited mobility or cognitive impairment, for whom direct tablet use would be impractical.

Importantly, both modes produce identical structured data. From the standpoint of downstream analysis, a Mode A response and a Mode B response are interchangeable, which means that the analytic model does not need to distinguish between populations purely on the basis of how the data were captured. This unification is essential for making small-to-medium datasets usable, because it increases the effective sample size that any given analysis can draw on.

Figure 2

Representative Screens of the Questionnaire Application

Patient Selection (Mode B) **Yes/No Question** **Multiple Choice**

Data Analysis Method

The collected questionnaire responses are used to construct a clinical prediction model that estimates the probability that a given patient will experience a fall. In this pilot, we adopt logistic regression (Hosmer et al., 2013) as the primary modeling technique. The inputs are the patient's responses to the questionnaire, encoded as binary variables (1 for yes, 0 for no) where appropriate, and the output is the predicted probability of a future fall, bounded in the interval [0, 1]. Higher output values correspond to higher estimated fall risk.

Logistic regression was chosen for three reasons. First, it produces a calibrated probability that can be communicated to clinicians and patients more intuitively than an uncalibrated score. Second, the model coefficients are directly interpretable, which is important in a clinical setting where the reasons for a given risk estimate may need to be explained to the patient or to a multidisciplinary team. Third, it performs reasonably even with the modest sample sizes that are available in the pilot phase, whereas more expressive models would require substantially more data to avoid overfitting.

To analyze the relationship between fall occurrence and questionnaire items, we examine the fitted coefficients and their associated confidence intervals. Items with large, statistically credible positive coefficients contribute most to the estimated probability of falling and are therefore candidates for targeted intervention. This interpretability is an explicit design property of the analytic pipeline, not a byproduct.

Results and Validation

The developed questionnaire application was trialed at Kashiihara Hospital and Kanenokuma Hospital. The design of the trial was informed by prior evidence that information-technology-based fall prevention tools can reduce fall rates in acute care settings when embedded into clinical workflow (Dykes et al., 2010). Each institution received its own isolated instance, with its own branding, and administered the survey to a mixture of inpatients and outpatients over the trial period. The administrative console was used in parallel to monitor deployments and to verify that data were being recorded in the expected structure.

Across the two sites, the trial successfully collected questionnaire responses from several dozen patients. The data-listing and export functionality were exercised, and it was confirmed that structured data could be recovered as CSV for subsequent statistical analysis. These results demonstrate that the questionnaire application is operationally feasible under real clinical conditions, that both survey modes can be used in the same deployment, and that per-hospital data isolation does not impede aggregated research analysis.

At the time of this report, the pilot dataset is intentionally small and is used primarily to confirm feasibility rather than to report definitive risk estimates. Consequently, although the logistic regression pipeline was constructed, the emphasis of the present pilot is on validating the end-to-end data collection and analysis workflow rather than on the numerical performance of the fitted model. Initial exploratory fits are consistent with expectations from the literature in the sense that items related to prior fall history, mobility, and medication use contribute in the expected direction.

Discussion

The pilot demonstrates that a questionnaire-centered, tablet-administered pipeline for fall risk assessment can be deployed at multiple hospitals with acceptable operational overhead and that the resulting data can feed a logistic-regression-based risk model. Three aspects of the result merit discussion.

First, the two-mode design appears to be essential rather than incidental. A single-mode design that relied on patient self-assessment would have systematically excluded inpatients and cognitively impaired patients, who are arguably the most important population for a fall prevention system to cover. A single-mode design that relied on staff-assisted assessment would have imposed a burden on staff that scales with the number of outpatients, which is operationally undesirable. Supporting both modes, with a shared data schema, is what makes the pipeline viable across the full patient population.

Second, the decision to build the analysis around logistic regression is conservative by design. More expressive models, including Bayesian networks and proportional hazards models with time-varying covariates, are attractive long-term options, but they are also harder to fit reliably on small datasets and harder to explain in a clinical setting. Starting with logistic regression

establishes a baseline that later, more expressive models must meaningfully outperform to justify their additional complexity.

Third, the architecture separates data collection from analysis, which means that improvements to either side can be made independently. New items can be added to the questionnaire without requiring changes to the analytic pipeline, and the analytic pipeline can evolve (for example, to incorporate free-text responses or transcribed speech processed via natural language techniques) without forcing a redesign of the user-facing application.

At the same time, several limitations must be acknowledged. The pilot dataset is small, and the current fit of the prediction model should therefore be understood as a feasibility check rather than as a validated clinical tool. The two participating hospitals share a regional profile, which may limit the external validity of any coefficients fit from their combined data. And the questionnaire, although tuned for elderly users, still relies on self-reported information, which is subject to recall and social-desirability biases; triangulating questionnaire responses against sensor data remains an important future direction.

Conclusion

This paper has described a pilot study of a fall-risk-assessment-based support system for fall prevention training. The study combined a survey of existing fall risk assessment methods, the development of a tablet-based questionnaire application that supports both patient self-assessment and staff-assisted assessment, and the design of a logistic-regression-based analysis method for estimating the probability of a future fall. The system was trialed at two partner hospitals, where it successfully collected questionnaire data from several dozen patients and confirmed the feasibility of practical deployment with per-hospital data isolation.

The principal future challenges identified by the pilot are threefold. First, the volume of collected data must be increased, both by extending the duration of deployment at existing sites and by adding new partner institutions, so that the prediction model can be fit and validated on a dataset of clinically meaningful size. Second, the accuracy of the analysis model must be improved, including through the evaluation of alternatives to logistic regression such as proportional hazards models and Bayesian networks, and through the extraction of latent risk factors from free-text responses and from everyday conversation using natural language processing and speech recognition techniques. Third, mechanisms must be investigated for feeding fall-risk analysis results back to users in a way that actively promotes fall-prevention behavior, closing the assessment–feedback–prevention loop that motivates the entire research program. Addressing these challenges is expected to move the system from the present pilot stage toward a deployable tool that contributes to maintaining the quality of life of older adults.

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Declaration of Generative AI and AI-Assisted Technologies in the Writing Process

The authors declare that large language models (Anthropic Claude and Microsoft Copilot) were used to assist with English-language drafting and proofreading of the manuscript based on the authors' original Japanese-language presentation materials and prior notes. The usage was limited to translating, rephrasing, and refining statements for clarity and grammatical correctness in English. The ideas, research design, system implementation, data collection, analytic procedures, findings, and discussion are originally developed and derived from the authors' own research, and were reviewed and approved by all authors before submission.

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CMA-ES-Guided RVD-Based Layout and Building Generation Method for Aging-Friendly Industrial Parks

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Abstract

With rapid urbanization, industrial parks have become critical spatial carriers for economic development; however, large-scale construction often leads to degraded outdoor environmental performance, including thermal discomfort, poor ventilation, and excessive solar exposure. Traditional performance-driven design workflows rely on post-evaluation simulations, which are computationally expensive and inefficient in early design stages (Attia et al., 2013; Negendahl, 2015). This study proposes an integrated generative design framework that couples morphology generation, machine learning-based performance prediction, and multi-objective optimization to improve environmental performance in industrial park design. At the layout level, a Covariance Matrix Adaptation Evolution Strategy (CMA-ES) is applied to optimize Voronoi-based land subdivision under multiple constraints (Hansen, 2006). At the building level, a Rectangular Voronoi Diagram (RVD)-based method is introduced to generate flexible and modular building morphologies (Dillenburger, 2010). A dataset of 5,000 samples is constructed using parametric generation and simulated using Ladybug Tools, with the Universal Thermal Climate Index (UTCI) as the primary performance metric (Bröde et al., 2012). Machine learning models, particularly XGBoost, are trained to establish mappings between morphological parameters and environmental performance (Chen & Guestrin, 2016). Finally, a multi-objective optimization framework based on NSGA-II is implemented (Deb et al., 2002). Results demonstrate that the proposed method significantly improves design efficiency and enables early-stage performance feedback, providing a scalable and data-driven approach for environmentally responsive industrial park design.

Keywords: generative design, industrial park, environmental performance, machine learning, UTCI

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Introduction

Industrial parks serve as key spatial infrastructures supporting economic growth and urban expansion. However, large-scale developments often result in degraded environmental conditions at the block scale, including poor ventilation, excessive heat accumulation, and reduced outdoor comfort (Taleb & Musleh, 2015; Weerasuriya et al., 2020). These issues not only affect human well-being but also increase energy consumption and reduce urban sustainability.

Conventional design workflows typically follow a “design first, evaluate later” paradigm, relying heavily on simulation tools such as CFD and radiation analysis. While accurate, these methods are computationally expensive and inefficient for early-stage design exploration (Attia et al., 2013). As a result, designers face difficulties in integrating environmental performance into iterative design processes.

Recent advances in generative design and machine learning provide new opportunities to address these challenges. By integrating morphology generation, performance prediction, and optimization, performance-driven design frameworks enable efficient exploration of complex design spaces (Negendahl, 2015).

This study aims to develop a generative design framework that integrates computational geometry, machine learning, and multi-objective optimization to improve environmental performance in industrial park design.

Literature Review

Industrial Park Design and Urban Morphology

Industrial parks have evolved from single-function production zones into complex spatial systems integrating research, manufacturing, commercial services, and public facilities. Contemporary industrial parks therefore require not only efficient land utilization but also environmentally responsive spatial organization.

Previous studies have demonstrated that urban morphology strongly affects environmental performance. Morphological parameters such as building density, height variation, spacing, porosity, and spatial distribution significantly influence wind flow, solar access, thermal comfort, and microclimate conditions (Weerasuriya et al., 2020). In high-density urban environments, poorly configured building layouts can intensify thermal stress and reduce outdoor comfort.

Researchers have proposed numerous quantitative indicators to describe urban morphology and its environmental effects, including Sky View Factor (SVF), Frontal Area Index (FAI), porosity, and building coverage ratio. These studies reveal that urban environmental performance is highly sensitive to spatial configuration and building arrangement.

Generative Design and Computational Geometry

Generative design methods have been increasingly applied in architecture and urban planning to explore complex design spaces. Common approaches include parametric modeling, cellular automata, graph-based methods, Voronoi subdivision, and evolutionary algorithms.

Voronoi diagrams are widely used in spatial partitioning because of their flexibility and adaptability to irregular site boundaries. Compared with fixed-template planning methods, Voronoi-based subdivision enables more diverse and adaptive spatial organizations.

Evolutionary algorithms are particularly suitable for solving high-dimensional optimization problems involving multiple constraints. Among these methods, Covariance Matrix Adaptation Evolution Strategy (CMA-ES) has shown strong performance in continuous optimization tasks due to its adaptive covariance update mechanism and robust search capability (Hansen, 2006).

At the architectural scale, Rectangular Voronoi Diagram (RVD)-based methods provide an alternative to traditional modular building generation approaches. Unlike standard Voronoi systems that often generate irregular polygons, RVD methods maintain rectangular partitions, which are more compatible with architectural modularization and construction logic.

Environmental Performance Simulation and Machine Learning

Environmental performance optimization traditionally relies on simulation software such as CFD, Radiance, EnergyPlus, and Ladybug Tools. These simulation tools provide accurate environmental analysis but often require extensive computation time, limiting their integration into iterative design workflows (Negendahl, 2015).

Machine learning methods have recently emerged as efficient alternatives for performance prediction. By training predictive models using datasets generated through parametric modeling and environmental simulation, researchers have demonstrated that machine learning can accurately estimate environmental performance while significantly reducing computational costs.

Among existing machine learning methods, ensemble learning approaches such as Random Forest and XGBoost have shown strong prediction performance in architectural and urban applications. XGBoost is particularly effective because of its high prediction accuracy, regularization mechanism, and ability to generalize across complex datasets (Chen & Guestrin, 2016).

Methodology

Workflow Overview

This study proposes a three-stage workflow integrating generative modeling, environmental performance prediction, and multi-objective optimization.

The workflow consists of:

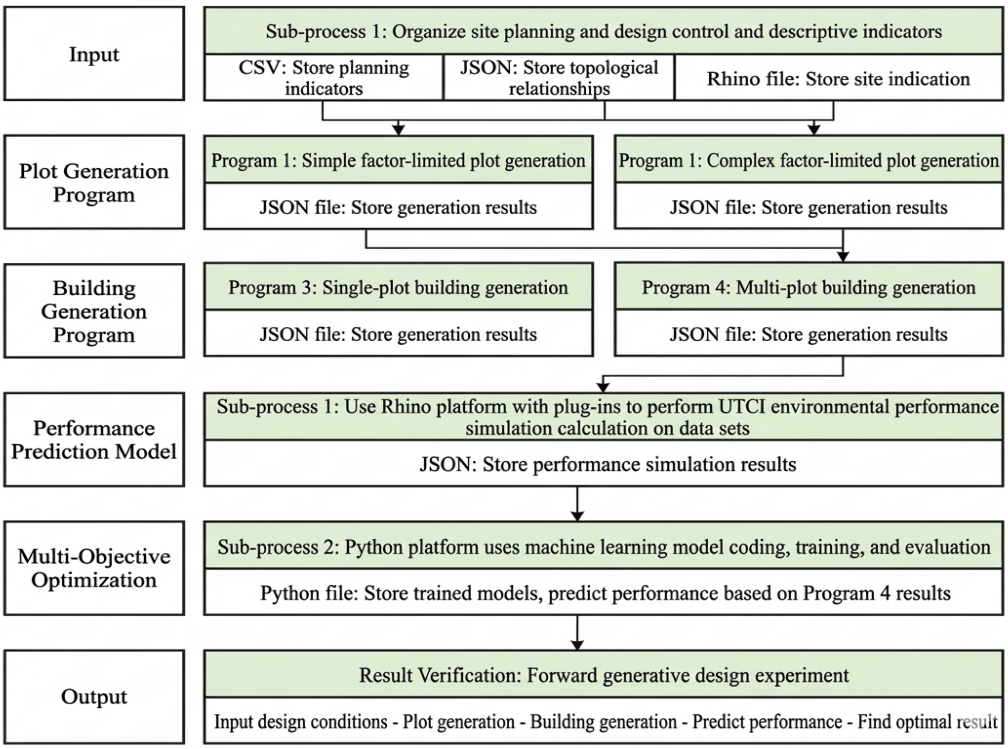
1. Morphology generation
2. Environmental performance prediction
3. Multi-objective optimization

At the urban layout level, land subdivision is generated using Voronoi-based geometry combined with CMA-ES optimization. At the building level, a RVD-based generation method is used to create flexible building morphologies. Environmental performance datasets are then generated through UTCI simulation using Ladybug Tools. Machine learning models

are subsequently trained to predict environmental performance indicators. Finally, NSGA-II optimization is applied to obtain Pareto-optimal solutions.

Figure 1

Overall Generative Design Workflow Integrating Morphology Generation, Performance Prediction, and Multi-objective Optimization



Land Subdivision Using CMA-ES

At the layout level, a CMA-ES algorithm is applied to optimize Voronoi-based land subdivision under multiple constraints, including topology, area distribution, and functional clustering (Hansen, 2006).

A multi-objective loss function is designed to guide the optimization process, ensuring that generated layouts satisfy both geometric and functional requirements.

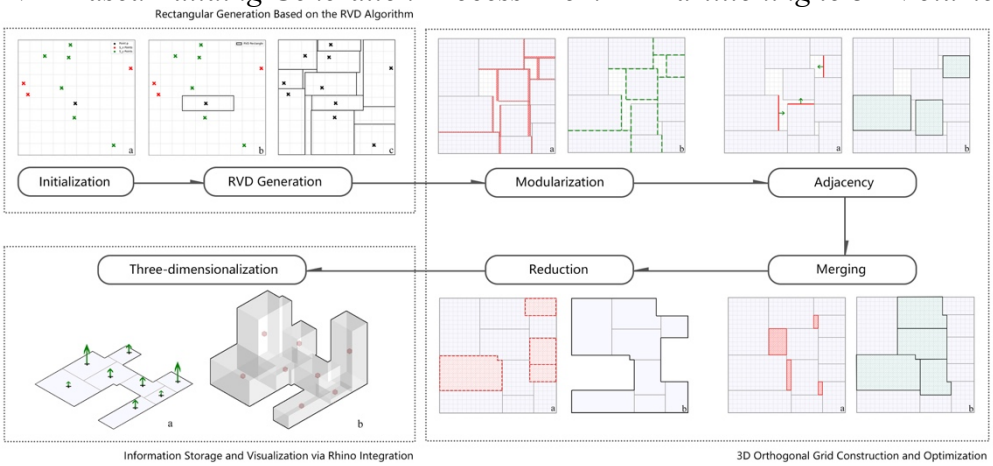
Building Generation Using RVD

At the building scale, a Rectangular Voronoi Diagram (RVD) is introduced to generate flexible building morphologies (Dillenburger, 2010).

Compared to traditional fixed templates, the RVD method allows for greater adaptability and diversity. The generation process includes: Modularization, Adjacency optimization, Space filling, Volume reduction, Three-dimensional extrusion.

Figure 2

RVD-Based Building Generation Process From 2D Partitioning to 3D Volumetric Forms



Environmental Performance Modeling

The Universal Thermal Climate Index (UTCI) is selected as the primary performance metric due to its ability to integrate multiple environmental factors, including temperature, radiation, humidity, and wind speed (Bröde et al., 2012).

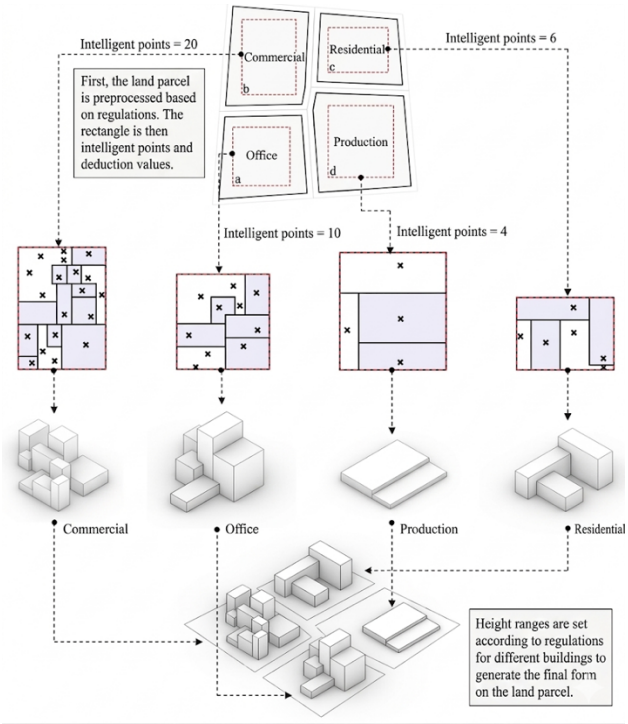
Two indicators are used:

- Average UTCI (aveUTCI)
- Standard deviation of UTCI (stdUTCI)

A dataset of 5,000 samples is generated and simulated using Ladybug Tools.

Figure 3

Visualization of UTCI Simulation Results Across Generated Urban Layout



Machine Learning Prediction

To improve computational efficiency, machine learning models are trained to predict environmental performance. Among various models, XGBoost is selected due to its high accuracy and robustness (Chen & Guestrin, 2016).

The model establishes a mapping between morphological features and environmental performance indicators.

Multi-objective Optimization

A NSGA-II algorithm is applied to optimize building layouts with two objectives:

- Minimizing average thermal stress
- Minimizing spatial variability

The optimization process produces a set of Pareto-optimal solutions, enabling designers to balance multiple performance criteria (Deb et al., 2002).

Results and Discussion

The proposed framework successfully generates diverse industrial park layouts that satisfy complex planning and environmental constraints.

At the urban layout level, the CMA-ES-based land subdivision method demonstrates strong adaptability when handling irregular site boundaries and multiple functional requirements. Compared with conventional subdivision approaches, the proposed method generates more organized and functionally coherent layouts while maintaining topology and area constraints.

At the architectural scale, the RVD-based building generation system produces flexible and modular spatial configurations. Compared with traditional fixed-template generation methods, the proposed approach enables greater morphological diversity while preserving constructability and modular consistency. The generated building forms also demonstrate adaptability under different density and height constraints.

The environmental simulation results indicate that urban morphology significantly affects outdoor thermal comfort distribution. Variations in building density, spacing, and height influence UTCI performance and spatial thermal variability. In particular, more balanced building distributions tend to improve thermal comfort consistency across outdoor spaces.

The integration of machine learning significantly reduces computational time compared with traditional simulation-based workflows (Negendahl, 2015). Among the tested prediction models, XGBoost demonstrates the highest prediction accuracy and strongest generalization capability. The comparison between machine learning prediction results and Ladybug simulation results shows strong consistency, validating the reliability of the prediction framework.

The NSGA-II optimization results reveal clear trade-offs between average thermal comfort and spatial variability. Some solutions achieve lower average UTCI values but exhibit higher spatial fluctuations, while others provide more balanced thermal distributions. This

demonstrates that environmental optimization should consider multiple objectives simultaneously rather than relying on a single performance indicator.

The generated Pareto-optimal solutions provide designers with multiple design alternatives under different environmental priorities. This flexibility is particularly valuable during the early conceptual design stage, where rapid iteration and performance feedback are critical.

Figure 4
Selected Optimized Building Configurations Under Different Performance Trade-Offs

Conclusion

This study proposes a performance-driven generative design framework for industrial park layout and building morphology generation.

By integrating CMA-ES optimization, RVD-based morphology generation, machine learning prediction, and NSGA-II multi-objective optimization, the framework enables efficient exploration of environmentally responsive urban configurations.

The results demonstrate that the proposed method improves both environmental performance and computational efficiency. Compared with traditional simulation-driven workflows, the framework allows environmental considerations to be integrated into the early stages of design, supporting a more iterative and performance-oriented design process.

The study also demonstrates the feasibility of combining computational geometry, environmental simulation, machine learning, and evolutionary optimization into a unified workflow for urban design applications. The proposed framework provides designers with diverse design alternatives while maintaining planning constraints and environmental objectives.

In addition to industrial park design, the framework has potential applications in broader urban and architectural scenarios requiring environmentally responsive spatial generation.

Future work may focus on integrating real-time sensing data, expanding environmental evaluation indicators, and incorporating additional human-centered performance metrics such as visual comfort, walkability, and behavioral analysis.

Declaration of Generative AI and AI-Assisted Technologies in the Writing Process

The author declares that AI-assisted tools were used to refine the language and structure of the manuscript. The research design, methodology, analysis, and conclusions are entirely the author's original work.

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Bridging the Spiritual Gap: A Practice-Based Approach to Developing a Culturally Appropriate Spiritual Needs Assessment Tool for Older Adults in Singapore

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Abstract

While the Biopsychosocial-Spiritual (BPSS) model is a standard framework used in gerontological social work, practitioners often report feeling unequipped to address the spiritual domain, particularly in culturally diverse Asian contexts. This practice-based research, conducted with 11 practitioners from Presbyterian Community Social Services and FILOS in Singapore, explored this gap through two focus groups investigating practitioners' understanding of and engagement with spirituality among older adults. Findings revealed three primary reasons for practitioner unpreparedness: a lack of formal training, the inadequacy of current BPSS assessment methods, and conceptual ambiguity conflating spirituality with religion. Practitioners further identified barriers including language and cognitive limitations, fear of proselytization, and insufficient knowledge of other faiths. In response, participants co-developed an innovative toolkit featuring conversational cards (both physical and digital) designed with culturally nuanced, open-ended questions exploring themes of meaning, hope, connection, and legacy without Western or religious bias. This paper reports on the first two phases of an ongoing practice-research project, including the participatory design of the "Inner Garden Spirituality Conversational Cards." The toolkit is currently being piloted and validated with older adult clients. The goal is to disseminate this validated, culturally sensitized resource to other agencies, empowering practitioners to provide more holistic and person-centered spiritual care.

Keywords: spirituality, older adults, practice research, cultural sensitivity, social work

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Introduction

The global phenomenon of an aging population presents profound challenges and opportunities for social service systems worldwide. Singapore, in particular, has experienced a dramatic demographic shift. As of 2025, the population of Singaporeans aged 65 and over exceeded 20% of the total for the first time, making the city-state the first country in Southeast Asia to reach that level of aging (Takeda, 2025). Concurrently, the number of citizens aged 80 and older jumped by 60% in the past decade (National Population and Talent Division, 2025). These trends are accompanied by a rise in seniors living alone, with one-person households more than doubling since 2003 to 15.6% in 2023/2024 (ChannelNewsAsia, 2025). Singapore has been recognized as the world's sixth Blue Zone, an engineered longevity hotspot with the world's lowest rate of cardiovascular mortality and the highest healthy life expectancy (Buettner, 2023). However, longevity without holistic well-being, including spiritual health, remains an incomplete societal achievement.

Within gerontological social work, the Biopsychosocial-Spiritual (BPSS) model has emerged as a standard framework for conducting comprehensive assessments (Saad et al., 2017). This model acknowledges that human well-being cannot be reduced to biological, psychological, and social dimensions alone; spirituality is a core component of the self, especially among older adults facing illness, disability, and mortality (Mondia et al., 2010). Yet, despite the model's widespread adoption, practitioners in Singapore consistently report feeling unequipped to address the spiritual domain. Ground sensing by community partners revealed that social workers experience discomfort and a lack of competencies in spirituality-related conversations with their clients, even when clients initiate these discussions. This practice gap formed the impetus for the present study, which initiated a practice research project in June 2025 with two social service agencies serving older adults: Presbyterian Community Social Services (PCSS) and FILOS Community Services. The overarching aim was to better understand the barriers to spiritual assessment and to co-develop a toolkit to assist practitioners in having culturally appropriate conversations about spirituality.

Literature Review

Defining Spirituality in the Context of Aging

Spirituality is a multidimensional construct that has been distinguished from religion, though the two are often conflated in practice. Religion typically takes place within established institutions and structures that aim to facilitate spirituality, whereas spirituality is broader, encompassing an individual‘s search for meaning, purpose, hope, connection, and transcendence (Pargament et al., 2013). For older adults, spirituality often becomes more salient as they confront losses, declining health, and approaching end of life. The search for meaning and purpose in life has been documented as a strong existential and emotional need for older people, especially those aged 75 years and older (Kalyani, 2009). Within the realm of psychosocial adjustment, Erikson's (1963) postulated crisis of integrity versus despair at the final stage of life highlights the critical role of integrative processes in healthy aging.

Kalyani (2009) have expanded our understanding of the inner processes that occur among older adults who integrate their past, present, and future selves while navigating the various facets of personal identity. Meaning and purpose are intertwined with spiritual matters and values, which are themselves connected to ethnic norms and beliefs. Belak and Goh (2024), in a multicultural Singaporean sample, found complex relationships between death anxiety and

religiosity, suggesting that spiritual needs vary significantly across cultural and religious groups. However, Saad et al. (2017) caution that the many meanings of "spiritual" across disciplines and cultures pose challenges for clinical application.

Spirituality and Well-being in Later Life: Empirical Evidence

A growing body of evidence demonstrates that spirituality and religiosity contribute significantly to quality of life among older adults. Jung et al. (2023) examined the association between volunteering, religiosity, and quality of life among older Singaporeans using data from a national survey. They found that both informal and formal volunteering were associated with better quality of life. Notably, while private prayer did not moderate this association, religious attendance did where the positive association between volunteering and quality of life was stronger among those attending religious services less frequently. These findings support the resource-compensation perspective, suggesting that volunteering may serve as a compensatory mechanism for older adults who are less integrated into religious congregations (Jung et al., 2023).

In the broader Asian context, recent research among elderly Thai Buddhist meditators has revealed significant mental health benefits associated with dedicated spiritual practice. A study by Glushich et al. (2025) found that practitioners who demonstrated perfect adherence to the Five Precepts (abstaining from killing, stealing, sexual misconduct, lying, and intoxicants) combined with regular death contemplation (maranasati) meditation showed significantly higher levels of inner strengths, well-being, gratitude, and life satisfaction, as well as lower levels of anxiety, depression, and aggression compared to less dedicated peers. These findings highlight the synergistic benefits of combining rigorous ethical conduct with contemplation of impermanence in fostering resilience and psychological flourishing among older adults (Glushich et al., 2025).

The Gerotranscendence Framework and Spirituality

Gerotranscendence, a developmental theory of positive aging proposed by Tornstam (2005), postulates that older persons break through old boundaries and transcend developmental crises when they face the reality of later life with a new paradigm. This theory has particular relevance for understanding spirituality in later life, as both religiosity and gerotranscendence promote active efforts to find intrinsic satisfaction and deeper emotional relationships as individuals age (Chia, 2019).

In a Singaporean case study examining the role of religiosity in gerotranscendence among older members of the Methodist Church, Chia (2019) identified several forms of religiosity: extrinsic, intrinsic, devout, overzealous, and superficial. The extrinsic, intrinsic, and devout forms generally promoted gerotranscendence, whereas overzealous and superficial forms hindered it. This finding suggests that whether religiosity contributes positively to spiritual development in later life depends critically on the form of religiosity practiced, not merely its presence or absence. This nuanced understanding has important implications for how practitioners assess and support spiritual needs among older adults from religious backgrounds.

Spirituality in the Singaporean Multicultural Context

Singapore is a natural laboratory for researchers studying cross-cultural and cross-religious social dynamics due to its multicultural, multilingual, and multi-religious population (Kalyani,

2009). According to recent census data, the three major ethnic groups, Chinese, Malay, and Indian comprise approximately 76.8%, 13.9%, and 7.9% of the population respectively, with religious affiliations closely correlated with ethnic distribution. The majority of Chinese are Buddhists or Taoists, the majority of Indians are Hindus, and almost all Malays are Muslims (Kalyani, 2009).

This multicultural context shapes how spirituality is expressed and experienced among older Singaporeans. Kalyani's (2009) qualitative study of older Singaporeans aged 70–84 years found that spirituality served as a means for achieving integration in both personal and community spheres. The study, which included participants from all three major ethnic groups with diverse religious affiliations (Muslims, Christians, Chinese religionists, Hindus, Sikhs, and others), revealed that older adults draw upon their spiritual resources to navigate the challenges of aging, including declining health, loss of loved ones, and changing social roles.

Further evidence from a qualitative study exploring aging experiences among ethnically diverse older Singaporeans found that adaptation to age-related changes included several spirituality-linked strategies. Participants reported using the "power of prayer," relegating responsibilities to a higher spiritual power, and engaging in community and religious social activities as methods of self-managing psychological and social health (Shiraz et al., 2020). The study identified five main themes in older adults' perceptions of health: slowing down, relationship harmony, financial harmony, social connectedness, and eating together. Adaptation strategies included "keep moving," "keep learning," adopting avoidant coping behaviors, "it feels good to do good" (finding meaning through helping others), the "power of prayer," and social participation (Shiraz et al., 2020).

Cultural Nuances in Spiritual Expression Among Asian Older Adults

The expression of spirituality among Asian older adults often differs from Western conceptualizations in ways that have important implications for assessment and intervention. In many Asian cultures influenced by Confucian, Taoist, and Buddhist traditions, aging perspectives often prioritize acceptance, familial interdependence, and spiritual harmony over individual autonomy (Liou & Morgan, 2026). A study of older adults in rural Taiwan found a preference for "tranquil aging" characterized by acceptance and following the mandate of heaven, remaining unaffected by social changes, and concern about children's futures—a model rooted in Eastern philosophy that contrasts with the active aging framework dominant in Western contexts (Liou & Morgan, 2026).

Similarly, research on middle-aged Singaporeans' views of successful aging identified four main themes: social factors (social participation and cohesion), physical health factors (physical slowdown and continued activity), financial factors (balance between independence and monetary transfers), and psychological factors (positive attitudes and religion) (Sayri, 2025). Among these, financial factors received the highest acknowledgment from participants, followed by physical, social, and psychological factors, suggesting that successful aging frameworks must account for pragmatic concerns alongside spiritual and psychological dimensions.

Existing Spiritual Assessment Tools and Their Limitations

Several standardized tools have been developed internationally to assess spiritual needs. The FICA Spiritual History Tool (Faith/Belief, Importance, Community, Address/Action) is widely

used by clinicians to integrate spiritual history into routine care (Puchalski & Romer, 2000). The Spiritual Distress Assessment Tool (SDAT), specifically developed for hospitalized older adults, measures four dimensions: Meaning, Transcendence, Values, and Psychosocial Identity (Mondia et al., 2010). Other tools include the Spiritual Index of Well-Being (SIWB), the SSOP (Screening for Spiritual Needs), and the Religious/Spiritual Struggle Scale (Exline et al., 2014).

While these tools have demonstrated validity in Western clinical settings, practitioners in Singapore have questioned their cultural relevance. Many of these tools assume a theistic or Judeo-Christian framework that may not resonate with seniors whose spirituality is expressed through ancestral veneration, filial piety, or non-theistic Buddhist practices. Moreover, local practitioners have noted that these tools are often not designed for community-based social work settings, where seniors may have lower literacy, cognitive impairments, or limited English proficiency. The need for culturally sensitive, accessible spiritual assessment tools tailored to the Singaporean context remains largely unmet.

The Practice Gap: Why Are Practitioners Unprepared?

Despite the recognized importance of spirituality in holistic care, a significant gap exists between the theoretical endorsement of spiritual assessment and its practical implementation. A locally developed Bio-Psychosocial-Spiritual Assessment Guide for Health and Social Work (Singapore Association of Social Workers, 2023) provides a framework, yet practitioners continue to report feeling unequipped to speak about the spiritual domain with their clients. This practice gap formed the impetus for the present study. Differential rates of active life expectancy by religion and religiosity among older Singaporeans (Saito et al., 2017) further underscore the need for nuanced, culturally informed spiritual assessment that can inform care planning and resource allocation.

The existing literature thus reveals a paradox: while spirituality is widely recognized as essential to holistic gerontological care, and while evidence demonstrates its benefits for older adults' well-being, practitioners lack the training, tools, and confidence to address this domain effectively. This is particularly acute in multicultural Asian contexts like Singapore, where spiritual expression takes diverse forms that resist easy categorization within Western assessment frameworks.

Research Questions

The present study therefore addresses the following research questions:

- Research Question 1: Why are social service practitioners still unequipped in assessing their seniors on spirituality-related needs?
- Research Question 2: What are the barriers for social service practitioners in assessing and working with their seniors on spirituality-related needs?
- Research Question 3: What can help social service practitioners be more ready in assessing and working with their seniors on spirituality-related needs?

Methodology

Research Design and Setting

This study employed a qualitative, participatory practice research design. The research was conducted in partnership with two Singaporean social service agencies namely: Presbyterian

Community Social Services (PCSS), and FILOS Community Services which provides community support and programs for olders adults in the community.

Participants

A purposive sample of 13 eligible practitioners was recruited from both agencies. Inclusion criteria were: (a) currently working with older adults (aged 60+) in a social service capacity, and (b) having at least one year of experience in gerontological practice. Eleven participated as two were absent from the focus groups. The participants comprised five participants from PCS and six from FILOS. Demographic characteristics are summarized in Table 1.

Table 1
Demographic Characteristics of Focus Group Participants

Participant Code	Gender	Age Range	Years of Experience	Designation	Religion
P1	Male	51–60	> 10	Senior Social Worker	Christian
P2	Male	61–70	> 20	Social Work Supervisor	Christian
P3	Female	41–50	10	Social Worker	Christian
P4	Male	41–50	7	Social Worker	Christian
P5	Male	30–40	1	Social Worker	Christian
F6	Male	41–50	7	Social Worker	Christian
F7	Female	31–40	12	Senior Case Manager	Islam
F8	Male	41–50	5	Social Worker	Christian
F9	Female	31–40	9	Social Worker	Christian
F10	Male	51–60	15	Senior Counsellor	Christian
F11	Male	31–40	2	Manager	Christian

Note. P = Presbyterian Community Social Services; F = FILOS Community Services.

Data Collection

Two semi-structured focus groups were conducted in August 2025, each lasting approximately 90 minutes. Focus groups were facilitated by the first author, a senior social work educator with over 25 years of practice experience. The interview guide explored six domains: (1) personal and professional understanding of spirituality, (2) current practices in addressing spiritual needs, (3) gaps and needs in spiritual support, (4) ideas for a spirituality support toolkit, (5) organizational and systemic support, and (6) closing reflections. All sessions were audio-recorded and transcribed verbatim.

Data Analysis

Transcripts were analyzed using Braun and Clarke's (2006) six-step approach to thematic analysis, facilitated by NVivo 14 software. Analysis proceeded through familiarization, initial coding, theme generation, theme review, theme definition, and write-up. Two researchers independently coded the first transcript to establish intercoder reliability ($\kappa = 0.84$), with discrepancies resolved through discussion. Member checking was conducted by presenting preliminary findings to three participants for verification.

Results

Findings are organized around the three research questions that emerged from the practice problem.

Research Question 1: Why Are Social Service Practitioners Still Unequipped in Assessing Their Seniors on Spirituality-Related Needs?

Three major themes were identified.

Theme 1: Lack of Formal Training and Guidance

Practitioners consistently reported an absence of structured learning opportunities on how to integrate spirituality into their work. As one participant stated, "As far as I'm aware, I don't think there's any tool that we are using… The rest of y'all can correct me if I'm wrong" (P1). Another noted, "I think personally, frankly, there isn't much training. When I've been through different social services, like FSCs and smaller SSAs, then now in FILOS and community mental health, there isn't specific training for any talk about spiritual stuff" (F6). A third participant simply concluded, "There's no… feels like there's no training in that sense lah" (F9). These quotes illustrate a pervasive gap in both preservice education and in-service professional development.

Theme 2: Inadequacy of Current Assessment Methods (BPSS)

While the BPSS framework is standard, its spiritual component is often treated as an afterthought, leading to superficial data collection. One practitioner observed, "BPSS is still the standard, but I can tell you the spiritual part always has the shortest answer… always has the least content" (F8). Another highlighted the problem of client response: "The thing is, a lot of the elderly, they themselves also don't quite understand the question… when we ask them, do you have any spiritual… they always say, 'oh, I'm Taoist, I'm Buddhist,' and that's it" (F11). Even when practitioners attempt to go deeper, the conversation remains tethered to religion:

"If you go through the BPSS, then under the S part, usually I'll ask, okay, do you have any religions? Then, how does this actually help you, support you…" (P4).

Theme 3: Conceptual Ambiguity and Conflation With Religion

Practitioners noted that both they and their clients often conflate spirituality with religion. One participant articulated a sophisticated distinction: "Basically, they in their whole life journey go through a lot of religion, but it doesn't really guide their whole life behavior or approach" (F8), seeing spirituality as the deeper "guiding principle." Another offered a hierarchical model: "Religion is part of the spiritual… overarching. Yeah, so spiritual is still broad in a sense, but then one of the smaller components is the religion aspect" (F9). However, in practice, "the tendency of elderly understanding… spirituality tends to weigh heavily on their faith and belief" (F6), funneling broader conversations into narrower religious labels.

Research Question 2: What Are the Barriers for Practitioners in Assessing and Working With Their Seniors on Spirituality-Related Needs?

Three additional themes emerged regarding barriers.

Theme 1: Language, Communication, and Cognitive Barriers

Practitioners noted that many older adults have limited English proficiency, lower educational attainment, or mild cognitive impairment, making abstract spiritual concepts difficult to discuss. This barrier was compounded by the lack of culturally appropriate vocabulary in Mandarin or Chinese dialects for terms like "spirituality" or "meaning."

Theme 2: Practitioner Discomfort and Fear of Proselytization

Practitioners, especially those with a personal faith, were cautious about being perceived as pushing their own beliefs. One participant explained, "For me, when I ask questions about spirituality, they may think that I want to talk about Christianity to them" (P4). Another acknowledged a boundary violation: "I did ask some of them, maybe have you considered going church? Or divert them to reading the Bible, or a simple prayer. Which may cause them to be defensive lah" (P5). A colleague noted that "resistance can come from co-workers that are overcautious… they might have very bad experience in the past… therefore they are very fearful… reaction is always to stay away" (F9).

Theme 3: Lack of Knowledge About Other Faiths

Practitioners felt that insufficient knowledge of other religious traditions made them hesitant to explore spirituality deeply. One simply stated, "lack of knowledge for us… about other religion" (P3). Another called for practical guidance: "Cultural sensitivity, so a toolkit that also helps to guide, let's say Christians or maybe Muslims, what are the things that are the so-called do's and don'ts" (F10).

Research Question 3: What Can Help Practitioners Be More Ready?

Three themes pointed toward solutions.

Theme 1: Need for Practical, Accessible Tools and Prompts

Practitioners expressed that they did not want theoretical manuals; they wanted simple, ready-to-use tools. One requested a "practical guide… maybe to ask people question… maybe how we can be ready and good in that conversation" (P4). Another suggested gamification: "When you gamify the facilitation or anything that you want to do, and you gamify it, such as giving them cards, like playing games, they are very actively and very vocal" (F8). A younger practitioner suggested technology: "Short videos definitely help, because that's what the culture is now… using certain technology lah. Like, I'm using Notebook LM… the toolkit could be put in such a way that users can ask questions" (F6).

Theme 2: Desire for a Framework Focused on "Meaning and Purpose"

To move beyond the religion-spirituality conflation, practitioners suggested using more accessible concepts. One explained: "I think when we gear towards meaning and purpose… seniors, if you get older, there will be a lot of losses… So after that, they have meaning and purpose in one stage of their life… So we need to find, at this stage of life, what is meaningful and purposeful for you?" (F10). Another agreed: "It might be easier to say, hey, I want to find out from you what is the meaning and purpose for you in life, compared to asking them, I want to talk to you about issues of spirituality" (F7).

Theme 3: Importance of Organizational Support and Normalization

Practitioners emphasized that individual tools would be insufficient without organizational backing, including supervision, policy integration, and recognition of spiritual care as a legitimate component of professional practice.

Discussion

This practice-based research set out to understand why social service practitioners in Singapore feel unequipped to address the spiritual needs of older adults despite the widespread adoption of the Biopsychosocial-Spiritual (BPSS) framework. Through focus groups with 11 practitioners from two community agencies, we identified several interconnected explanations for this practice gap, each of which has implications for tool development and practice improvement.

Interpretation of Findings

Practitioners consistently reported an absence of formal training on spirituality, a finding that aligns with international research documenting the marginalization of spiritual content in social work curricula (Edward et al., 2019). Oxhandler and Pargament (2014) found that while most practitioners view spirituality as relevant to practice, fewer than one-third report receiving any formal training on how to address it. Our findings extend this literature to the Asian context, where cultural norms around discussing existential matters may further compound educational neglect. The consequence, as Hodge (2006) observed, is that practitioners remain stuck at the earliest stage of spiritual competence—lacking even basic frameworks for initiating conversations.

The inadequacy of current BPSS assessment methods emerged as a second major finding. Practitioners reported that the spiritual component of BPSS assessments consistently yields the

shortest and most superficial responses, with clients typically responding only with a religious label ("I'm Buddhist, I'm Taoist"). This reflects what Saad et al. (2017) termed the "operationalization problem" in biopsychosocial-spiritual models—the tendency to treat spirituality as a demographic checkbox rather than a dynamic, meaning-making process. Pargament (2011) distinguished between "thin" descriptions of spirituality (simple demographic data) and "thick" descriptions (rich accounts of meaning, coping, and connection). Our findings suggest that current practice remains at the "thin" level, partly because practitioners lack training and partly because existing tools do not guide deeper exploration.

Conceptual ambiguity surrounding spirituality versus religion constituted a third theme. Practitioners demonstrated sophisticated conceptual distinctions, recognizing spirituality as the broader construct encompassing religion as a subset, yet struggled to translate this distinction into practice with clients who tended to equate spirituality with religious affiliation. This tension between practitioner conceptualization and client understanding has been documented elsewhere. Zinnbauer et al. (2015) found that while clinicians distinguish spirituality from religion, lay populations frequently use the terms interchangeably. Among older adults in Asian contexts, this conflation may be even more pronounced, as religious and cultural practices (e.g., ancestor veneration) are deeply intertwined (Kalyani, 2009). This gap between knowing and doing—declarative knowledge without procedural knowledge—is well documented in implementation science (Cabassa & Baumann, 2013).

Several barriers further impeded practitioners. Language and communication difficulties were salient in Singapore's multilingual context, where many older adults are more comfortable expressing existential concerns in Mandarin, Hokkien, Cantonese, or Malay than in English (Kalyani, 2009). Practitioner discomfort and fear of proselytization reflected both personal caution and organizational culture; several participants noted that coworkers who had "very bad experiences in the past" had become overcautious, "creating a climate where spiritual topics were implicitly discouraged." This pattern aligns with the concept of "spiritual bypass" in clinical practice—avoidance of spiritual topics due to discomfort, lack of training, or fear of boundary violations (Cashwell & Young, 2014). Finally, practitioners reported lacking basic knowledge about other faiths, making them hesitant to explore spirituality for fear of causing offense (Sue et al., 2009).

In terms of facilitators, practitioners requested practical, accessible tools rather than theoretical manuals. The suggestion to "gamify" the conversation through cards aligns with evidence that gamification reduces anxiety and facilitates disclosure in sensitive conversations (Cugelman, 2013). For older adults with cognitive impairments, visual and concrete prompts can facilitate communication (Bourgeois et al., 2004). Practitioners also expressed a strong desire to focus on "meaning and purpose" rather than explicit spiritual or religious language. This aligns with Frankl's (1959) logotherapy, which posits meaning-making as a universal human motivation, and with Wong's (2016) meaning-centered approach to positive aging, which emphasizes that meaning does not depend on religious belief. Finally, practitioners highlighted the importance of organizational support, including supervision, policy integration, and recognition of spiritual care as legitimate professional practice (Weiner, 2009).

Implications for Practice

Several implications follow from these findings. First, practitioners should shift from asking "What is your religion?" to exploring "What gives your life meaning and purpose?" These reframing respects diverse worldviews while gathering clinically relevant information about

spiritual resources and needs. Second, spiritual assessment should be recognized as an ongoing conversation rather than a one-time event, unfolding over multiple sessions as trust develops. Third, visual and conversational aids such as the Inner Garden cards that the authors developed can reduce the abstractness of spiritual topics and make exploration accessible to clients with cognitive limitations or limited English proficiency.

For social work education, the findings underscore the need to integrate spiritual competencies into curricula. Students should be able to define spirituality in culturally sensitive terms, initiate meaning-focused conversations, use structured tools, navigate religious diversity without proselytizing, and document spiritual needs appropriately. Currently, these competencies are not systematically taught in Singaporean social work programs.

At the organizational level, agencies should adopt formal spiritual assessment protocols integrated into standard intake and care planning. The Inner Garden toolkit is designed to fit within existing workflows, requiring no special equipment or extended time. Organizations should also develop clear ethical guidelines distinguishing appropriate spiritual assessment from proselytization, addressing when and how to initiate conversations, boundaries around sharing personal beliefs, and documentation standards.

At the policy level, funders and policymakers should recognize spiritual care as a legitimate component of holistic gerontological services. Currently, eldercare funding in Singapore prioritizes physical and medical needs, with limited resources allocated to psychosocial and spiritual support. The evidence base for spiritual care supports its inclusion in service standards and funding frameworks.

How the Inner Garden Toolkit Addresses the Identified Gaps

The Inner Garden Spirituality Conversational Cards were co-designed with practitioners specifically to address the gaps, barriers, and facilitators identified in the focus groups. The toolkit's 21 bilingual cards focus on universal themes such as meaning, hope, connection, resilience, belonging, and legacy rather than explicit religious categories. This design choice directly addresses the conceptual ambiguity and conflation of spirituality with religion by providing accessible entry points for all clients regardless of religious affiliation or non-affiliation.

To address the lack of formal training, the toolkit includes a facilitator guide with scripts and video instructions (briefing and roleplay), requiring minimal training for implementation. The cards are physical, ready-to-use tools that address practitioners' request for practical, accessible resources that can be deployed immediately without extensive preparation. The gamified, card-based format reduces practitioner discomfort and fear of proselytization by shifting the focus to the client's existing resources and experiences rather than the practitioner's beliefs.

The bilingual design (English and Mandarin) directly addresses language and communication barriers, while the 5-point rating scale provides a low-stakes way for clients to express their spiritual state. Probing questions on each card guide practitioners toward "thick" descriptions of spirituality without requiring specialized knowledge of different faith traditions. The toolkit is designed for low-threshold organizational adoption, easily integrated into home visits or center-based activities.

The Inner Garden toolkit differs from existing spiritual assessment tools in several important ways. Unlike the FICA tool (Puchalski & Romer, 2000), which explicitly references "faith" and may alienate non-religious clients, the Inner Garden cards use inclusive language accessible to all. Unlike the SDAT (Mondia et al., 2010), developed for hospitalized older adults in Western contexts, the Inner Garden cards were co-designed with Singaporean practitioners for community-based settings. The toolkit is not intended to replace existing tools where they are appropriate but rather to serve as a first-line, low-barrier resource that can be used with all clients.

Limitations and Future Directions

Several limitations should be acknowledged. The sample was predominantly Christian (10 of 11 participants), which may have influenced both the barriers identified and the toolkit design. Future research should include more practitioners from Muslim, Buddhist, Hindu, and non-religious backgrounds. The focus groups were conducted in English, potentially excluding practitioners more comfortable in other languages. Pilot testing with older adults is currently underway; the toolkit's effectiveness in improving spiritual outcomes has not yet been empirically established. Future research should examine the toolkit's psychometric properties, implementation conditions, client outcomes, and cross-cultural applicability in other Asian contexts.

Conclusion

This practice-based research addressed a critical gap in gerontological social work in Singapore: practitioners' persistent discomfort and lack of readiness to address the spiritual needs of older adults. Through focus groups with 11 practitioners from two agencies, we identified three root causes (lack of training, inadequacy of current methods, conceptual ambiguity) and three barriers (language/cognitive limitations, fear of proselytization, lack of knowledge about other faiths). In response, the researchers and the practitioners co-designed the Inner Garden Spirituality Conversational Cards, a culturally nuanced toolkit that uses accessible prompts focused on meaning, purpose, hope, and connection rather than explicit religious language.

The implications of this study are threefold. For practice, the toolkit provides a concrete, low-threshold resource that agencies can adopt without extensive training. For education, the findings underscore the need to integrate spiritual assessment competencies into social work curricula. For policy, organizations should consider normalizing spiritual care through supervision and documentation frameworks. Future research should examine the toolkit's psychometric properties, its applicability across different religious and non-religious populations, and its impact on client-reported spiritual well-being and quality of life. The ultimate goal is to disseminate this validated, culturally sensitized resource to other agencies, empowering practitioners to provide holistic and person-centered spiritual care to Singapore's rapidly aging population.

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Declaration of Generative AI and AI-Assisted Technologies in the Writing Process

The authors declare that Grammarly and co-Pilot were used in proofreading and refining the language used in the manuscript. The usage was limited to correcting grammatical and spelling errors and rephrasing statements for accuracy and clarity. No generative AI was used to generate content, ideas, data analysis, or interpretations. The ideas, design, procedures, findings, analyses, and discussion are originally written and derived from careful and systematic conduct of the practice research.

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Shared Silence: The Lived Realities of Spouses of Older Adults With Dementia in Kolkata

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Abstract

The greying population of modern society live in a deepening care-crisis as the primary care unit, the family, is passing through an existential crisis shaped by declining fertility, declining family size and growing dispersal of family members. For the elderly citizens suffering from degenerative ailments such as Alzheimer's or Parkinson's disease, who need round-the-clock care, the crisis is even deeper. Although ideally, dementia care demands a network of doctors, nurses, domestic aides, and relatives, the primary responsibility lies with the family members, the spouses, in particular. Care arrangement and the quality of care vary depending on the age, physical agility, economic condition, the mental makeup, and the value-resolve of the spouses. This paper examines how dementia caregiving reshapes the everyday lives, emotional well-being, and social identities of elderly spouses who serve as primary caregivers. The paper, based on a study of 16 families with elderly citizens suffering from Alzheimer's in Kolkata, highlights the psychological strain, erosion of personal autonomy and the sacrificial adjustments and compromises that the spouses as caregivers make in their lives. Conducted in collaboration with the Alzheimer's and Related Disorders Society of India (ARDSI), Calcutta Chapter, the study adopts an ethnographic, descriptive phenomenological approach. Drawing from detailed case studies, the paper illustrates the lived experiences, endurance, and resilience of aged dementia caregivers in modern urban India.

Keywords: family, elderly citizens, dementia, care crisis, care-givers, sacrifice, sufferings

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Introduction

Mutual care has been one of the universal functions of the family all over the globe; this holds good even for the Indian family system. However, with increasing geographical dispersion of families, ageing, and declining health, providing care has become more difficult. Over the past two decades, traditional joint families have given way to nuclear or single-member households due to urbanisation, migration, and broader socio-economic shifts driven by liberalisation and neo-liberalism. These changes have reshaped education, employment, family structure, and old-age planning, while reducing state support in key sectors, thereby placing greater responsibility on individuals and families.

In this context, the ageing population—especially in urban middle-class settings like Kolkata—faces a growing "care crisis." The situation is particularly difficult for elderly individuals suffering from degenerative conditions such as Alzheimer's and Parkinson's disease. With the number of dementia patients in India rising rapidly, the burden of care falls largely on family members, especially spouses.

Despite extensive medical research on dementia, the lived experiences of caregivers remain underexplored. Care-giving involves intense emotional, physical, and social challenges that significantly reshape caregivers' daily lives, well-being, and social relationships, making it essential to study care not just as a medical issue but as a deeply social and relational process.

The Context of the Study

Statistics indicate that dementia affects 5.2 million people in India (Alzheimer's and Related Disorders Society of India, 2020), a figure projected to rise to 16.39 million by 2050 (figure portrayed in the website of Alzheimer's and Related Disorders Society of India, Calcutta Chapter). A nationwide study published in Alzheimer's and Dementia: The Journal of the Alzheimer's Association (Lee et al., 2023) estimates a 7.4% prevalence among adults aged 60+, with 8.8 million elderly Indians living with dementia. While extensive research has examined the medical and psychological aspects of degenerative conditions such as Alzheimer's, vascular, and Lewy Body dementia, far less attention has been paid to caregivers, who provide continuous support to affected older adults.

At the same time, India is witnessing a steady rise in its ageing population due to declining fertility and increasing life expectancy. According to the *State of the World Population Report 2018* by UNFPA, despite population growth from 566 million in 1971 to 1.35 billion in 2016, fertility rates have fallen, with the total fertility rate dropping to 2.0 in 2023—below the replacement level of 2.1 (Choudhary, 2018). Within a neoliberal, market-driven context marked by economic uncertainty, individuals increasingly make calculated life choices—such as delayed marriage, career prioritisation, controlled reproduction, and migration—that are more pronounced in urban India. This rationalisation of life has led to the rise of nuclear and lone-member households, intensifying the care crisis for the elderly. Many older adults, often living alone, rely on professional caregivers or move to old age homes. Yet, emotional, social, and health-related insecurities, shaped by isolation and separation from family, persist.

Elderly citizens are differentially positioned by gender, class, family structure, and health, with health being a key determinant of quality of life in urban India. Those with minor ailments are better placed than those with severe conditions, who depend on others for daily care. Individuals with complex diseases like Alzheimer's are almost entirely reliant on caregivers.

The illness not only affects the patients but also deeply impacts family members, who often make career compromises while coping with the emotional strain of witnessing a loved one's decline. Even hired caregivers must bring empathy and compassion to their role. Thus, the lives of elderly persons with Alzheimer's have two dimensions: (1) the medical aspect, managed by professionals, and (2) the socio-cultural-economic aspect, handled by family members. In India, the absence of a comprehensive state-supported care policy places the primary responsibility on families, despite limited support from NGOs with constrained resources.

This paper examines the impact of caregiving on family members, focusing on changes in everyday life, emotional well-being, and social roles in the context of long-term dementia care. Primary caregivers often experience significant stress, anxiety, and burden as they balance household responsibilities, professional commitments, and intensive care demands. While some adopt coping strategies such as personal time, leisure, or hobbies, for most, opportunities for self-care remain limited due to the relentless nature of care-giving.

Methodology

This paper draws on ongoing research on dementia caregiving conducted in collaboration with the Alzheimer's and Related Disorders Society of India (ARDSI). Fieldwork involved close engagement with the ARDSI Calcutta Chapter through meetings, extended observation, and participation in memory clinics. Access to caregivers in Kolkata was facilitated through ARDSI, supplemented by respondents identified via personal networks.

Interviews were conducted exclusively with caregivers who provided informed consent and voluntarily agreed to participate in the study. The majority of interviews were carried out telephonically, each running over sixty to ninety minutes. In addition, in-depth, face-to-face interviews were conducted with five respondents at their residences. Given their proximity and preference for personal interaction, these interviews were conducted in naturalistic settings, allowing for richer contextual understanding through direct observation and sustained interaction. Clarifications and elaborations were sought from the respondents on repeat calls at the time of writing transcripts.

All interviews were guided by a pre-designed interview schedule and were audio-recorded with participants' permission. To date, data have been collected from sixteen respondents and subsequently transcribed for analysis. As the study is ongoing, further data collection will continue over the coming months. The narratives presented in this paper are largely descriptive in nature and aim to preserve the participants' voices and lived experiences with minimal interpretive distortion.

As the experience and progression of dementia vary from person to person, the experiences of caregivers in providing care and comfort to their loved ones also differ significantly. Capturing the complexity of dementia caregiving through a fixed set of parameters is inherently challenging, as caregivers' journeys are shaped by diverse emotional, relational, and contextual factors. Nevertheless, for this research and to develop an ideal-typical understanding of the caregiving experience, this study conceptualises caregivers' lives through a set of analytical categories. These include the emotional burden of caregiving; changes in everyday routines; transformations in conjugal relationships; alterations in leisure activities and opportunities for time alone; and, finally, the emergence of moments of happiness and emotional meaning within the context of dementia.

The Families of the Patients

Of the 16 patients in the study, 10 are female, and 6 are male. Reflecting dementia's age-related nature, 6 are aged 66–75, 6 are 76–85, 3 are 86–95, and 1 is below 65. Eight patients have lived with the condition for less than five years, and eight for more than five years. In terms of occupation, 6 were homemakers, 3 school teachers, and one each was a scientist, lawyer, private company executive, engineer, and railway staff member, while 2 were bank employees.

Of the 16 patients, 2 belong to five-member families, 7 to four-member families, 6 to three-member families, and 1 is unmarried. Eleven reside in sub-nuclear households—either living alone with hired caregivers due to spousal loss or with a spouse while children live elsewhere. One lives in a nuclear household, one in a supplemented nuclear, and one in a supplemented sub-nuclear arrangement. This reflects the ongoing nuclearisation of urban middle-class families, indicating a declining capacity of the family as the primary care unit, further weakened by dispersal and work pressures.

Among the sixteen caregivers interviewed, 5 (31.25%) are male and 11 (68.75%) females. Women—especially wives and daughters—predominantly assume primary caregiving responsibilities, even when not co-residing with the care recipient. In contrast, male caregivers, mainly husbands and sons, tend to rely on paid support due to their role as primary earners and work pressures. This reflects persistent gendered divisions of labour, where care-giving remains feminised and male participation is viewed as an exception, typically in the absence of an able-bodied female family member.

Dementia, in most cases, catches the individuals aged 65 and above, while most caregivers are either middle-aged (9) or older people (6) or adult children (1), many of whom are themselves ageing and balancing multiple health, personal, and social obligations. A majority of the caregivers (15) are well-educated, have access to health information and are of middle-class background, who are capable of informed decision-making. The families that came under the study were nuclear (3), sub-nuclear (8), joint household (1), supplemented nuclear (1) and supplemented sub-nuclear (3) households. Most caregivers (14) are married, with spouses viewing care as a moral and emotional responsibility, even as marital relationships become reshaped by dependency, strain, and loneliness; the few widowed (1) and unmarried (1) caregivers likewise demonstrate resilience and strong commitment despite personal vulnerability.

In terms of occupation, among women caregivers, 5 are teachers, 2 homemakers, 1 nursing staff member, 2 government employees, and 1 runs a business. Male caregivers are employed in law (2), banking (1), and the private sector (3). Twelve caregivers belong to financially secure or upper-middle-class households, while 4 report financial insolvency. Seven live separately from care recipients and provide remote supervision through hired caregivers; 4 reside in the same city but in separate households and offer direct oversight. A majority (13 out of 16), irrespective of gender, rely on hired caregivers due to work commitments, while ageing spouses also depend on paid assistance. Only 3 respondents prefer not to hire caregivers, citing moral commitment. Overall, financial stability alleviates but does not eliminate the economic and emotional burden of long-term dementia care, which often still requires extended family support.

Among the 16 patients, 11 share cordial and emotionally supportive relationships with their primary caregivers, maintaining meaningful interaction even when recognition is impaired. In

contrast, 3 have strained relationships, where the combined burden of illness and caregiving leads to emotional exhaustion, irritation, and reduced quality of interaction. In one case, a caregiver continues to struggle with accepting her husband's condition and, at times, perceives him almost as a stranger. There are also two cases in which the relationship between the patient and caregiver had been poor before the onset of dementia. However, after cognitive decline—particularly when the patients became calmer and more subdued—the quality of their relationship improved notably.

Changes in Spouses' Lives After Dementia

In this study, 13 of 16 respondents reported that a loved one's dementia diagnosis profoundly transformed their lives, reshaping family roles, emotions, and social and work engagements. Caregivers assumed responsibilities for care, supervision, finances, and emotional support, leading to role redefinition, emotional strain, and social withdrawal. Despite grief, fatigue, and "ambiguous loss," many adapted over time through coping strategies and continued to view caregiving as a moral commitment grounded in compassion and enduring relationships.

Mrs Sumita Ghosh's (69) life has undergone a profound transformation following her husband's dementia diagnosis, as she has become the primary caregiver, managing his daily needs, household responsibilities, and constant supervision despite her own health challenges. The demands of caregiving have left her physically exhausted and emotionally strained, marked by grief, sadness, and a sense of loss as she witnesses the gradual decline of her once independent and strong partner. Her social life, personal interests, and self-care have significantly diminished, and although she finds brief moments of solace in music and routine activities, her life is now largely shaped by responsibility, isolation, and continuous adaptation to her husband's increasing dependence.

This case study shows that spousal dementia caregiving is a deeply transformative and burdensome experience, marked by physical exhaustion, emotional strain, and social isolation. It highlights how caregivers gradually reorganise their lives around responsibility and loss, while continuing to adapt with resilience despite limited personal well-being.

Balancing Professional Responsibilities With Care-Giving

In this study, 5 of 16 respondents reported considerable difficulty in managing professional responsibilities alongside the intensive demands of caregiving. The dual burden of employment and sustained care created persistent time pressures, role conflict, and emotional strain, as caregivers were required to constantly negotiate between workplace expectations and the unpredictable needs of a spouse with dementia. This often resulted in compromised work performance, reduced efficiency, and heightened anxiety, alongside physical exhaustion.

To manage competing demands, caregivers adopted adaptive strategies such as hiring professional help, delegating household tasks, seeking support from family, and adjusting work commitments. While these measures offered partial relief, emotional and supervisory responsibilities largely remained with the spouse. Despite fatigue and stress, most caregivers continued to sustain both roles, guided by a strong sense of duty, emotional attachment, and moral obligation, often internalising caregiving as an integral part of marital commitment.

Over time, this prolonged engagement in dual roles became a transformative experience. It reshaped caregivers' priorities, often leading to the reevaluation of career ambitions, social

engagements, and personal aspirations. Simultaneously, it fostered the development of emotional resilience, patience, and adaptive coping capacities. Many caregivers reported a deepened understanding of care as an ethical and relational practice, as well as a more nuanced appreciation of family bonds, responsibility, and interdependence.

Thus, while the simultaneous management of professional and care-giving roles generates significant strain, it also contributes to processes of personal transformation, highlighting the complex interplay between burden, adaptation, and meaning within the care-giving experience.

Conjugal Life After Dementia

Dementia profoundly reshapes not only the daily routines of family caregivers but also the relational dynamics between caregivers—particularly spouses—and persons living with the illness. As dementia progresses, previously reciprocal relationships, especially spousal relationships grounded in mutual emotional exchange and shared decision-making, are gradually transformed into asymmetrical arrangements characterised by dependency and sustained care. Spousal caregivers increasingly assume roles as managers, protectors, and emotional anchors, marking a fundamental reconfiguration of spousal and familial roles and responsibilities.

This relational shift is further intensified by behavioural and personality changes in the person with dementia. Spouses living with dementia may exhibit altered emotional responses, including withdrawal, passivity, suspicion, or agitation, challenging caregivers' earlier perceptions of their spouse's identity and shared marital history. Such changes disrupt relational continuity and compel spousal caregivers to renegotiate emotional bonds, expectations, and modes of interaction within an evolving caregiving context.

The erosion of reciprocity constitutes a central emotional challenge in spousal dementia care. As cognitive and emotional capacities decline, caregivers' expectations of recognition, emotional response, and appreciation often remain unmet, generating profound feelings of grief, loss, and emotional dissonance. Nevertheless, many spousal caregivers continue to provide care with patience and empathy, redefining spousal love and commitment beyond conventional notions of mutual exchange and companionship.

At the same time, dementia caregiving may also function as a site of relational transformation. In certain cases, sustained spousal care-giving fosters renewed emotional closeness, softening previously strained relationships and enabling new forms of intimacy grounded in empathy, attentiveness, and everyday care practices. Thus, dementia care is not solely a narrative of relational rupture but also one of redefinition and potential renewal, where care becomes a medium for emotional resilience, moral devotion, and rediscovered connection.

Krishanu Ganguly (73), a retired advocate of the Kolkata High Court, lives in Salt Lake with his wife, Mrs Bani Ganguly (73), diagnosed with dementia in 2021. Their relationship had begun deteriorating nearly a decade earlier due to her behavioural and cognitive changes, including mistrust and delusional accusations, leading to emotional distress and loss of intimacy. The situation was compounded when uninformed family members believed her claims, causing stigma and isolation for MrGanguly. Although he now recognises these as symptoms of dementia, allowing some reconciliation, he regrets the delayed diagnosis that prolonged their suffering.

The case highlights how dementia caregiving profoundly transforms spousal relationships over time. As the illness progresses, marriages grounded in mutual companionship and reciprocity are gradually reconfigured into relationships marked by asymmetrical dependence and sustained emotional labour. Spouses increasingly transition from partners to primary caregivers, assuming responsibility for daily care, decision-making, and emotional management.

Intimacy is redefined through acts of care, patience, and vigilance rather than reciprocal exchange. While this shift is accompanied by loss, strain, and grief for the partner's former self, it may also foster new forms of closeness rooted in compassion, commitment, and enduring emotional bonds. Dementia care-giving does not simply erode spousal ties but reshapes them, creating new forms of intimacy grounded in care, responsibility, and ethical commitment. In this context, love becomes an enduring practice—sustained through presence, sacrifice, and emotional effort—rather than merely a shared feeling.

The Caregivers' Pursuit of Leisure and Emotional Renewal

A critical yet under-examined dimension of spousal dementia caregiving is the erosion of personal time. Caregivers become deeply embedded in the continuous physical, emotional, and logistical demands of care, leaving limited scope for self-care. Even when brief periods of respite are available, they are typically devoted to rest and recovery rather than meaningful leisure or self-development.

Consequently, activities that once sustained a sense of identity and personal fulfilment are progressively marginalised. The cumulative effects of fatigue and sustained responsibility produce monotony, emotional depletion, and a gradual attenuation of individual subjectivity.

Nearly all caregivers (15 of 16) demonstrated resilience by attempting to carve out limited personal time despite intense caregiving demands. Following the diagnosis, their daily routines and lifestyles were significantly disrupted. While many made deliberate efforts to include brief periods of rest or emotionally restorative activities alongside work and household responsibilities, most reported substantial curtailment of hobbies, travel, and social interactions due to caregiving obligations and concerns for their partner's safety.

In some cases, caregivers consciously sustained small leisure practices as coping mechanisms to preserve emotional well-being and a sense of self beyond the caregiving role. Overall, the constrained and negotiated nature of personal time emerges as a critical factor shaping caregivers' resilience, identity, and everyday caregiving experience. Here are some illustrations:

Arup Chatterjee (60), the primary caregiver of his wife Rina Chatterjee (60), diagnosed with dementia in 2020 and under treatment in Srirampur, has very limited personal time due to caregiving demands. Social interactions are irregular and contingent on care arrangements, while shared leisure and travel remain largely unfeasible due to her restlessness and need for constant supervision. Consequently, his mobility and autonomy are significantly constrained. Although he occasionally seeks personal respite, her condition limits such possibilities. As a coping strategy, he engages with online caregiving resources, reflecting his ongoing negotiation between duty, emotional commitment, and restricted autonomy.

Like Mr Chatterjee, Mrs Chaitali Mondal's (74) everyday life is largely structured by the demands of caregiving, leaving limited scope for personal pursuits. Nonetheless, she engages in small practices of self-care, such as solving Sudoku, taking brief walks, and maintaining social connections through digital platforms, which serve as sources of emotional support. Despite persistent fatigue, she continues to sustain an emotional bond with her husband, who occasionally demonstrates recognition through words or gestures, thereby reaffirming their enduring relational connection despite cognitive decline. Care-giving has also entailed significant personal sacrifices, particularly the curtailment of travel, as unfamiliar environments tend to heighten his anxiety and disorientation, leading her to gradually accept the long-term constraints imposed by dementia.

These cases show how spousal care-giving becomes an all-encompassing moral and practical responsibility, progressively constraining personal time, mobility, and social life. Everyday life decisions come to revolve around the needs of the partner with dementia, narrowing caregivers' personal worlds and blurring the boundaries between care and self.

Caregivers experience an ongoing tension between emotional commitment and personal autonomy, often leading to isolation and a sense of constraint. At the same time, they adopt coping strategies such as digital engagement and small acts of self-care. Despite cognitive decline, spousal bonds often endure through recognition and everyday gestures, reflecting a complex interplay of loss, resilience, and continuing intimacy.

Silent Suffering, Emotional Changes and Sacrifice

Caregivers often encounter significant difficulty in balancing professional obligations, personal needs, and social relationships alongside the demands of caregiving. The intensive and time-bound nature of care work frequently leads to the marginalisation of leisure, rest, and social engagement, resulting in increasing isolation and limited opportunities for physical and emotional recuperation.

In this study, 12 out of 16 respondents reported experiencing persistent stress and anxiety, reflecting the cumulative psychological burden associated with continuous caregiving. This strain is not only a product of physical exhaustion but also of emotional labour, uncertainty, and the long-term trajectory of dementia.

Moreover, prevailing cultural norms that frame caregiving as a moral and familial duty often inhibit caregivers from articulating their distress. Expressions of fatigue, frustration, or emotional strain may be perceived as a failure of commitment or devotion. Consequently, caregivers tend to internalise their struggles, rendering their suffering largely invisible and insufficiently acknowledged within both familial and social contexts. Here is an illustration:

Mrs Sujata Neogy's (67) experience highlights the profound emotional burden of long-term dementia caregiving. Following her husband's diagnosis in 2020, she became his primary caregiver, a role that led to sustained exhaustion, emotional strain, and psychological distress. In 2024, his admission to a specialised care home ensured better safety and professional support; however, this transition did not alleviate her burden. Instead, it gave rise to complex emotions such as guilt, loneliness, and a deep sense of grief over the gradual loss of their shared life. Her experience underscores that the impact of care-giving extends beyond active care, leaving enduring feelings of loss and moral ambivalence.

Mrs Neogy's case shows that the impact of dementia caregiving continues even after active care ends. While institutional care ensured her husband's safety, it left her with feelings of guilt, loneliness, and grief. Her experience highlights the lasting emotional effects of caregiving and the need to recognise and support caregivers beyond the period of direct care.

Moments of Happiness in Caregiving

Spousal dementia care-giving constitutes a highly demanding and time-intensive form of labour, encompassing not only physical care but also the ongoing management of progressive cognitive, emotional, and behavioural changes. As the illness advances, caregivers frequently reorganise their daily routines, priorities, and social lives around the needs of their partner, while simultaneously undertaking substantial emotional labour in contexts marked by limited or inconsistent reciprocity.

The cumulative burden of caregiving often results in persistent fatigue, stress, and emotional exhaustion. Caregivers may experience moments of frustration or irritability, often followed by guilt, as they recognise these reactions stem from the partner's condition rather than intent. Despite this, care-giving retains meaning: 13 of 16 respondents reported moments of emotional connection—such as shared smiles, recognition, or familiar routines—which provide vital emotional sustenance. Though brief, these moments reaffirm relational continuity and sustain caregivers' sense of purpose and motivation.

In contrast, 3 out of 16 respondents reported a decline in overall happiness following the diagnosis, attributing this to emotional loss, diminished reciprocity, and the gradual erosion of shared memories and companionship. This variation highlights the heterogeneous nature of caregiving experiences, shaped by factors such as coping capacity, the prior quality of the relationship, and the progression of the illness.

While moments of connection can mitigate emotional strain, caregivers' well-being often becomes closely intertwined with the comfort and condition of their partner, necessitating significant personal sacrifice. Opportunities for self-care and leisure, when available, offer important—albeit limited—relief and contribute to emotional regulation and resilience. However, their absence may intensify the perceived burden of care, leading to further psychological strain.

Overall, these findings underscore the complex interplay of burden, meaning, loss, and resilience within spousal dementia caregiving, highlighting the critical need to recognise and support caregivers' emotional well-being to sustain their health and the integrity of their relationships.

Support From Extended Family Members

Support from extended family—once central to the traditional Indian joint family system—has significantly declined in contemporary caregiving. While joint families historically shared emotional, financial, and physical responsibilities, urbanisation, migration, and the shift toward nuclear households have weakened these intergenerational support structures.

In the present study, a majority of respondents (11 out of 16) reported minimal or no involvement of extended family in caregiving, neither receiving nor expecting financial or emotional support beyond the immediate household—indicating a normalisation of reduced

kinship obligations. Respondents noted that relatives are often geographically dispersed across cities or abroad, limiting their involvement, and transforming extended family ties from functional support systems into largely symbolic relationships. Among the remaining respondents, only 5 out of 16 reported occasional expressions of concern from extended family members, which were largely limited to phone calls or sporadic inquiries about the well-being of the patient. Furthermore, 3 out of 16 respondents indicated that contact with relatives was largely confined to festive occasions, suggesting a ritualistic rather than supportive engagement. Strikingly, only 1 out of 16 respondents reported receiving consistent and meaningful support—whether emotional, financial, or practical—from extended family members.

Taken together, these findings point toward a broader shift in the structure and functioning of kinship networks in contemporary Indian society. The erosion of extended family support has led to an increased concentration of caregiving responsibilities within the nuclear family, often placing considerable strain on primary caregivers. This transformation not only reflects changing socio-economic conditions but also signals a redefinition of familial roles, obligations, and expectations in the context of long-term care.

Mrs Bani Ganguly's (73) pre-diagnostic phase was marked by severe behavioural changes, including delusions that led to accusations against Mr Krishanu Ganguly (73**,** retired advocate), causing social humiliation and isolation. Following the formal diagnosis, relatives began to recognise the illness, though this shift came after reputational damage. Subsequently, a few close family members offered emotional support, reflecting a delayed but important re-engagement of familial support.

Mrs Sumita Ghosh (59) reports limited contact with extended relatives, particularly from her husband's side, who seldom inquire about his health. Her sister and brother-in-law visit occasionally, and her daughter, who lives in Bally, visits approximately once every two weeks. In contrast, neighbours—especially young men in the locality—play a supportive role by regularly engaging Mr Ghosh in conversation and encouraging his evening routine. Over time, these neighbours have come to function as an important source of emotional support, akin to family members.

The case studies indicate that support from extended kin is limited and largely supplementary, with most caregivers relying primarily on themselves or immediate family members due to changing family structures and urban living. While extended kin may offer occasional emotional, financial, or temporary assistance, such support is irregular and insufficient to significantly reduce the caregiver's overall burden.

Difference Between Male and Female Caregivers

The study reveals a clear gendered pattern in the organisation and experience of caregiving, shaped by differential roles, expectations, and access to resources within the household.

Reliance on hired caregivers: Male caregivers (n = 5) tend to rely heavily on paid caregivers, adopting supervisory roles focused on coordination and monitoring rather than direct care. In contrast, female caregivers (n = 11) are less likely to depend on external support, often due to dissatisfaction with its quality and a strong sense of personal responsibility, leading them to undertake most caregiving tasks themselves.

Direct care-giving involvement: Women remain more actively engaged in the day-to-day care of their spouses, including assistance with personal hygiene, feeding, medication management, and constant supervision. Their caregiving role is continuous and physically demanding. Men, by comparison, provide more limited direct care, often stepping in only when necessary, while continuing to emphasise oversight and coordination rather than sustained physical involvement.

Household responsibilities: A clear gender divide is evident in the management of domestic work. Male caregivers are generally exempt from routine household responsibilities, contributing mainly through tasks such as errands, purchases, and bill payments. In contrast, female caregivers shoulder the dual burden of managing the household—cooking, cleaning, and organising daily routines—alongside intensive caregiving, significantly increasing their workload and limiting time for rest or personal well-being.

Financial and managerial roles: Men generally exhibit greater familiarity and confidence in managing financial matters such as banking, bill payments, and formal procedures. Women, particularly those with limited prior exposure, often report anxiety or lack of confidence in these areas. However, they demonstrate stronger competence in supervising domestic help and managing household functioning, reflecting their long-standing engagement in these domains.

Emotional and social outcomes: These structural differences shape distinct emotional experiences. Female caregivers report higher levels of stress, fatigue, frustration, and social isolation due to heavier, continuous workloads and limited support, with restricted mobility further reducing social interaction. In contrast, male caregivers, often relying on hired help and less involved in daily care, retain greater access to social spaces and tend to experience comparatively lower emotional distress.

Overall, these findings highlight how caregiving is deeply embedded within gendered divisions of labour, with women bearing a disproportionate share of both physical and emotional responsibilities, while men occupy more managerial and less intensive roles.

Conclusion

The study has found that spousal dementia caregiving in urban India is a deeply transformative social and emotional experience that extends far beyond the domain of medical responsibility. With the gradual decline of the traditional joint family system, dispersal of family members and weakening of kinship relations, the burden of care primarilyfalls on the spouses. The caring spouses, who are ageing as well, experience physical exhaustion, emotional strain, and social isolation, and, in the process, reshape their sense of self, everyday routines, and relationships. Caregivers frequently experience anticipatory grief, a prolonged process of mourning characterised by the gradual erosion of emotional reciprocity and companionship, alongside the decline of physical and mental health of the patient.

However, some of the caregivers develop forms of emotional resilience and adaptive coping, often deriving meaning from small, everyday moments of connection, recognition, or sharedsuffering and emotive coexistence. Reflecting on the shared happy memories rooted in mutual empathy and love keep the caregivers going. These moments, though fleeting, play a crucial role in sustaining caregivers psychologically and rejuvenating their resolve and purpose.

The burden of caregiving is, at times made heavier, with broader structural constraints. Limited public awareness about dementia, inadequate institutional support systems, and the absence of comprehensive policy frameworks in the Indian context leave caregivers with minimal external support. As a result, care-giving remains largely privatised, with families navigating complex challenges in isolation.

Hence, the study underscores the urgent need to reconceptualise dementia caregiving as a broader social issue rather than a purely private or familial responsibility. It calls for greater recognition at the policy level and the development of accessible support mechanisms, including community-based services, caregiver support programs, and institutional care infrastructure, which are currently absent in India.

Declaration of Generative AI and AI-Assisted Technologies in the Writing Process

The theme and subject of this paper are original, and the work is based exclusively on data derived from my fieldwork. The manuscript has been written in my own words; however, I have utilised AI tools, particularly Chat GPT, for the purposes of editing, enhancing clarity and precision, and improving the overall quality of the language. Other than Chat GPT No other AI tools have been used in writing this manuscript.

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Designing for Bathroom Safety: Understanding Older Adults' Support Behaviors and Grab Bar Needs

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Abstract

As Taiwan officially transitioned into a super-aged society by the end of 2025—with the population aged 65 and above exceeding 20%—ensuring home environmental safety has become a core issue for implementing "aging in place." This study aims to investigate the functional roles and spatial constraints of support systems used by older adults in bathroom environments, where accidental falls are most prevalent. Through situational observations, expert consultations, and semi-structured interviews with older adults, the research identified significant "support gaps" in existing layouts, revealing that in the absence of professional grab bars, older adults frequently rely on washbasins and door frames for compensatory support during sit-to-stand and transfer movements. These improvised methods, dictated by environmental deficiencies, pose a high risk of injury. To mitigate these risks, the study established three core design dimensions: structural safety, behavior-oriented configuration, and de-institutionalized aesthetics. The findings emphasize that bathroom safety must evolve from the mere addition of individual grab bars toward a "systemic functional integration" of spatial equipment. Specifically, by seamlessly integrating grab bar functions into furniture elements, the design effectively eliminates the clinical feel of medical devices, thereby increasing the psychological acceptance and willingness of older adults to utilize these supports. By implementing "continuous support trajectories" and "invisible assistive concepts," the proposed guidelines provide an empirical framework for designing safer, more dignified, and inclusive living environments. Ultimately, this research seeks to enhance independence and confidence, supporting older adults in living safely and with dignity within their familiar home environments.

Keywords: older adults, bathroom safety, grab bar design, support behaviors, aging in place

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Introduction

Taiwan's population aged 65 and above has exceeded 20% of the total population by the end of 2025, marking its official transition into a super-aged society (National Development Council, 2025). As the elderly population grows rapidly, ensuring home environmental safety has become a core issue in implementing "aging in place" policies. Among all areas within the home, bathrooms and toilets are identified as the most common sites for accidental falls among older adults (Ng et al., 2022).

Recent research emphasizes that physical environmental factors are the most common cause of falls, accounting for 30% to 50% of incidents (World Health Organization, 2007). This high-risk nature makes bathroom modifications—such as the installation of grab bars—a critical priority for fall prevention programs. Studies have shown that specific environmental interventions, including the addition of grab bars and non-slip surfaces, are essential for mitigating hazards in these high-risk zones (Ng et al., 2022).

Preliminary observations reveal a critical lack of appropriate assistive devices in many older adults' homes, with the absence of stable support being the most severe issue. In the absence of professional grab bars, older adults frequently rely on washbasins or towel racks for compensatory support during sit-to-stand and transfer movements. Supporting these observations, recent research emphasizes that such indoor environmental deficiencies significantly heighten the fear of falling, forcing individuals to adapt their movements to perceived environmental hazards (Parab et al., 2025). These non-professional support methods are often restricted by spatial layouts and pose significantly high risks of injury, as existing home hazards often force older adults into unstable movement patterns.

To address the safety crises inherent in a super-aged society, this study focuses on "grab bars" as a core intervention. By conducting field observations and expert reviews, this research aims to investigate older adults' support behaviors and the associated spatial constraints. Ultimately, this study proposes safety-oriented design recommendations to provide older adults with a safer and more dignified living environment, supporting their independence in daily activities.

Literature Review

The Current Status of Aging in Taiwan

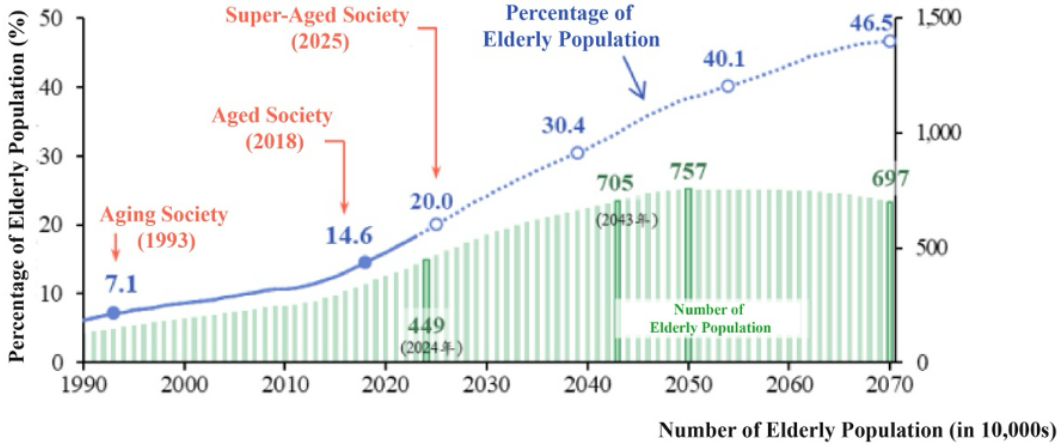
Taiwan is undergoing a rapid demographic transformation. According to the National Development Council (2025), the population aged 65 and above reached 4.67 million by the end of 2025, accounting for 20% of the total population and officially marking Taiwan's transition into a super-aged society. Furthermore, the "oldest-old" (aged 85+) now represent 9.92% of the elderly demographic. This accelerating trend underscores the urgent need for systemic bathroom safety and evidence-based design guidelines for aging in place.

This phenomenon stems from the dual influence of declining mortality and birth rates (Hsu, 2022). Advances in medical science have increased average life expectancy; conversely, shifts in modern perspectives on marriage and childbearing, combined with heavy economic competitive pressure and the sub-replacement fertility, have slashed in the younger population (Jones, 2019). This structural shift represents more than just a demographic

change; it poses severe challenges to the public health system and social care resources (Hsu, 2022).

Figure 1

Projections of the Aging Population in Taiwan (2024–2070)



Source: National Development Council (2024).
Note. The demographic data has been updated to 2025 based on the latest information from the National Development Council (NDC) website; however, the supporting charts are sourced from the 2024 NDC Annual Report, which remains the most recent official publication for visualized data.

Aging in Place

The community care philosophy of "Aging in Place" traces its historical roots back to Nordic countries in the 1960s. During this period, society began to critically reflect on the restrictive nature of large-scale institutions, which lacked privacy and stifled individuality, leading to the "Normalization" and "De-institutionalization" movements (Nirje, 1994). Originally aimed at advocating for the right of marginalized groups, such as those with disabilities, to enjoy a normal rhythm of life, the movement asserted that older adults should also be allowed to live and spend their final years within familiar community environments (Nirje, 1994). This ideology, which emphasizes community reintegration and rejects large-scale institutions, has since profoundly influenced global elderly care policies. As recent qualitative research confirms, the vast majority of older adults prefer to remain in their original residences or familiar communities. Their primary motivation is to maintain the autonomy of their personal living spaces and an independent lifestyle, thereby avoiding the loss of agency and the sense of confinement often associated with entering nursing facilities (Wiles et al., 2012).

Different nations have developed various support models based on their unique social contexts. Danish care policy centers on "Aging at Home," emphasizing the preservation of dignity and the subjectivity of older adults (Healthcare Denmark, 2019). Through a paradigm shift from institutional to home-based care, the policy utilizes structured rehabilitation to reshape the self-care capacities of the elderly, thereby reducing dependence on long-term support services. Similarly, the Japanese government has established "Community-based Integrated Care Centers" in every local district (typically covering school districts of approximately 20,000 residents). These centers, comprised of public health nurses, social workers, and care management specialists, are responsible for preventive care, consultation services, the coordination of community health resources, and comprehensive care management (Hatano et al., 2017). Taiwan officially incorporated "Aging in Place" as a core pillar of its national strategy with the implementation of the "Long-term Care 2.0" policy in

2017, striving to build a community-based care system (Ministry of Health and Welfare, 2016).

Hazards of the Bathroom Environment

As the aging population grows, “aging in place” has become a strategic priority for preserving the autonomy and dignity of older adults. However, conventional home environments often fail to accommodate age-related functional declines (e.g., ADL/IADL impairment), leading to significant fall risks (Parab et al., 2025; Tsai et al., 2020). Specifically, bathrooms are identified as high-risk zones due to their high dependency and the frequent absence of adequate support fixtures (Ng et al., 2022). Therefore, investigating the integration of bathroom assistive devices—such as grab bars—within spatial configurations is essential for mitigating movement-related hazards and supporting the realization of aging in place.

Although bathroom spaces occupy only a small portion of the home, their high frequency of use and slippery characteristics make them the areas with the highest incidence of accidents and the greatest difficulty in performing Activities of Daily Living (ADL) for older adults (Ng et al., 2022; Parab et al., 2025).

Existing environmental deficiencies, such as floor thresholds, a lack of appropriate support in sink and toilet areas, and overly narrow spatial dimensions, often lead to significant fall risks for older adults (Parab et al., 2025; World Health Organization, 2007). Therefore, optimizing the spatial configuration of bathrooms and the design of support facilities is critical to reducing accidents and supporting independent living for the elderly (Healthcare Denmark, 2019; Ng et al., 2022; Parab et al., 2025).

Methodology

Situational Observation Method

This study employs the situational observation method to collect data on older adults' assistive device usage and spatial utilization within bathroom environments. A purposive sampling approach was used to recruit three older adults as participants for the observation. Given the private nature of such activities, a “Simulated Behavioral Demonstration” approach is adopted. Participants are invited to demonstrate daily routines within a simulated setting, allowing for the observation of operational logic, spatial movement, and potential environmental hazards. To ensure data authenticity, researchers do not interfere with the participants' actions during the process. All sessions are video-recorded to facilitate precise behavioral subsequent video analysis.

Semi-structured Interview

Semi-structured interviews were conducted with the participating older adults to explore their behaviors observed during the sessions and their personal usage experiences. This approach aimed to gain a deeper understanding of the actual difficulties they encountered and their specific needs.

Expert Consultation and Design Guidelines

Following the conclusion of situational observations, the frequency of specific behaviors (such as compensatory support) was quantified, and the content of the semi-structured interviews with older adults was organized. Subsequently, the study proceeded to the expert consultation phase, involving in-depth interviews with two experts in the fields of aging and spatial design. This stage aimed to transform the empirical data derived from observations and interview findings into concrete design recommendations and guidelines for bathroom environments. Through a professional lens, the results from the previous stage were translated into Design Guidelines for Grab Bar Configuration.

Result

Data Analysis of Compensatory Behaviors

According to the situational observations of the three participants, a total of 20 compensatory support behaviors were identified during bathroom activities. The data, summarized in Table 1, reveals that the most frequent behavior was relying on washbasins for support during sit-to-stand transitions (n = 11, 55%). Other significant behaviors included using wall surfaces for stability (n = 4) and grabbing door frames instead of professional grab bars (n = 4) when entering or exiting the space.

The frequent reliance on washbasins indicates that when professional assistive devices are inappropriately positioned or completely absent, older adults instinctively seek the nearest horizontal surface to maintain their balance. When older adults in environments lacking professional grab bars are forced to rely on these unstable fixtures for compensatory support, the structural instability of these objects constitutes a significant environmental hazard, thereby exacerbating both the risk and the fear of falling (Parab et al., 2025; World Health Organization, 2007). As emphasized by Ng et al. (2022), the bathroom is a highly hazardous environment for older adults with functional limitations, and the lack of appropriate professional bathroom modifications (such as safety grab bars) exposes them to considerable danger. Although such compensatory behavior is common, it conceals an extremely high risk of slipping, especially in wet environments (Ng et al., 2022; Parab et al., 2025).

Table 1

Categorization of Observed Bathroom Hazards and Proposed Assistive Solutions

Frequency (n)	Sub-item Frequency	Item	Item Subcategories
1		Mobility Difficulties	
20		Compensatory Support Behavior / Lack of Support Points	
	4		Relying on wall surfaces for support during sit-to-stand and lowering transitions at the toilet.
	11		Using the sink for support when passing by due to the absence of grab bars

	4	Relying on door frames for support instead of grab bars when entering the bathroom.
	1	Standing up from a shower chair without grab bars and without any support point (no bathtub)
1	Fixture Placement	
1	Insufficient Space	

Semi-structured Interview

Through semi-structured interviews and situational observations of three older adults (Participants A, B, and C), this study identified three critical dimensions of bathroom-related challenges:

Physiological Bottlenecks in Postural Transitions and Vertical Instability

Strenuous Transitions. Participants B and C identified the "sit-to-stand" transition (especially after toileting or showering) as the most physically demanding task.

Postural Collapse Risk. While Participant A could manage upper-body tasks like hair washing, lower-body instability made "standing while showering" an extremely hazardous activity. This necessitates a forced reliance on shower chairs.

High Dependency on Specific Equipment. All participants exhibited a heavy reliance on specific personal items (e.g., shower chairs and anti-slip slippers). This indicates that the primary bathroom environment fails to provide fundamental balance support.

Environmental Support Gaps and the Threat of "Forced Falls"

Ineffective Environmental Support. Participant B exhibited a passive coping mechanism termed "forced falling" ("I just have to let myself fall"), driven by the total absence of reliable grasping points during moments of instability.

Distrust of Existing Fixtures. Participant C's concern regarding the structural integrity of washbasins ("I fear the sink will collapse if I grab it") reveals a deep-seated psychological doubt. This distrust limits the use of existing furniture for compensatory support.

Dual Psychological Burden: Fear of Falling (FoF) and De-labeling Needs

Post-traumatic Anxiety. Participant C's history of major spinal surgery has resulted in hyper-vigilance toward wet environments, manifesting as a persistent Fear of Falling (FoF).

Fear-Driven Defensive Behaviors. Participant A adopted the practice of "wearing anti-slip shoes while showering." This sacrifice of convenience and hygiene for a sense of security highlights a behavior pattern driven entirely by environmental anxiety.

Table 2
Analysis of Behavioral Observations and Psychological Burdens in Bathroom Environments

Analysis Dimension	Key Findings	Specific Behavioral Manifestations & Cases
Physiological Bottlenecks in Postural Transitions	Strenuous Transitions & Vertical Instability	"Participants B and C identified the 'sit-to-stand' transition as the most physically demanding task. Lower-body instability forced Participant A to rely on shower chairs and anti-slip slippers."
Environmental Support Gaps & "Forced Falls"	Ineffective Support & Structural Distrust	Participant B exhibited a passive coping mechanism termed "forced falling" due to the absence of grasping points. Participant C expressed psychological doubt regarding the structural integrity of washbasins.
Dual Psychological Burden: Fear of Falling	Fear-Driven Defensive Behaviors	Post-traumatic anxiety (spinal surgery) led Participant C to hyper-vigilance. Participant A's practice of "showering in anti-slip shoes" highlights a behavior pattern driven entirely by environmental anxiety.

Expert Consultation

Based on the quantitative results derived from situational observations, this study conducted in-depth interviews with two experts, Expert 1 and Expert 2, to transform behavioral data into practical design guidelines. These experts collectively pointed out that bathroom safety should not be viewed merely as the addition of individual assistive devices; rather, it requires a systemic integration across three dimensions: structural safety, behavior-oriented configuration, and de-labeling psychology.

Regarding structural safety, the study focuses on establishing "transitional safety strategies," which involve reinforcing the bases of existing fixtures and implementing edge-grip designs. Expert 1 suggests transforming existing equipment, such as washbasins, into support points by reducing the edge thickness to between 5 and 8 cm to allow for a secure hand grip. However, from a comprehensive defense perspective, Expert 2 reminds us that grab bars are only the last line of defense; the design's origin should prioritize the floor's anti-slip coefficient to compensate for the risks associated with the weight-bearing limitations of equipment.

In terms of behavior-oriented configuration, the experts emphasized that grab bar placement must precisely align with ergonomics and correspond to physical movements. Expert 2 detailed the functional differences, noting that horizontal grab bars are primarily responsible for the "pushing up" support during transitions between sitting and standing, while vertical grab bars are used for "holding on" to stabilize the body and prevent slipping. Expert 1 added that through the coordination of L-shaped grab bars, these can effectively serve as pivots to stabilize the center of gravity if dizziness occurs upon standing.

Finally, to uphold the dignity of older adults and reduce psychological resistance, designs should incorporate "de-institutionalized aesthetics." Expert 2 suggests avoiding the cold feel of medical-grade stainless steel in favor of materials that match the wall tones or possess a warm texture. Expert 1 advocates for a universal design mindset, concealing assistive functions within furniture-inspired "stopping points" to replace visually intrusive traditional grab bars. Through the formulation of these three core principles, this study aims to construct a more inclusive and secure bathroom environment for a super-aged society.

Established Design Guidelines

Through in-depth interviews with two experts specializing in aging and spatial design, this study successfully translated the observed compensatory support behaviors into actionable design guidelines with practical instructional significance. This phase ensured that the empirical behavioral data was professionally synthesized into ergonomic criteria for safer bathroom environments.

Principle 1. Structural Safety Priority

Core Objective is to alleviate psychological fear regarding equipment collapse by reinforcing the stability of hardware.

Platform-Mounted Configuration and Base Reinforcement. It is highly recommended to prioritize platform-mounted washbasins and reinforce their bases and wall-bearing points during the early stages of renovation. A solid physical structure provides strong psychological reassurance, convincing users that the equipment can withstand sudden impacts. This effectively eliminates the hesitation to seek support caused by the fear of "fixture detachment."

Edge-Grip Design. The front edge of the washbasin or counter should be designed with a thickness of 5–8 cm to facilitate a secure "web-grip" (clamping between the thumb and fingers). This design provides tangible tactile feedback, allowing users with limited manual dexterity to gain a sense of stability through gripping, thereby reducing anxiety when navigating slippery floor conditions.

Principle 2. Behavior-Oriented Configuration

Core Objective is to establish a continuous support trajectory and eliminate the sense of helplessness caused by a lack of accessible support points.

Continuous Support Trajectories. The placement of grab bars must consider the user's complete movement workflow within the bathroom. It ensures that at any moment of center-of-gravity transition, a stable support point remains within reach. This continuity significantly enhances the psychological safety of older adults and reduces the perceived lack of environmental control.

Functional Integration and Synergistic Support. Horizontal grab bars assist in the transition from sitting to standing, while vertical or L-shaped bars stabilize the center of gravity. Grab bars should be functionally integrated with bathroom fixtures such as showerheads, ensuring that users always have a stable support point for one hand while reaching for objects or performing tasks.

Principle 3. De-institutionalized Aesthetics and Psychological De-labeling

Core Objective is to preserve user dignity and reduce psychological resistance to assistive devices through "invisible" design.

Affective Material Application. Designers should avoid cold-toned metals (such as raw stainless steel) that carry strong medical connotations. Instead, materials with warm textures and colors that harmonize with residential interior styles should be utilized. By creating a warmer visual atmosphere, assistive equipment is transformed into "home furniture," mitigating the decline in self-efficacy associated with aging or injury and aiding in the restoration of psychological well-being.

Invisible Assistive Concept. Supportive functions should be subtly integrated into everyday environmental objects (such as reinforced washbasin edges or storage shelves that double as grab bars). This functional invisibility protects the user's autonomy and dignity, lowering the psychological barriers to using safety facilities and increasing the willingness to adopt preventive measures.

Discussion

This study employs situational observations, semi-structured interviews, and expert consultations to deeply analyze the behavioral patterns and psychological needs of older adults in bathroom environments. The following synthesis discusses the core research findings.

Ergonomic Crises Underlying Compensatory Behaviors

Findings reveal that over 55% of compensatory support behaviors occur in the washbasin area, uncovering a critical "support gap" in existing environments. This is particularly evident in rental housing, where older adults are often prohibited from drilling holes to install professional grab bars, forcing them to rely on non-professional fixtures like washbasins and door frames. While these "intuitive" behaviors address immediate balance needs, they overlook structural load-bearing limits. The proposed "edge-grip design (5–8 cm)" and "platform-mounted washbasins" specifically address this crisis by transforming hazardous fixtures into sturdy and graspable safety points, providing reliable support without the need for wall-drilling.

"Forced Falls" and the Perception of Environmental Discontrol

The psychological state of "forced falling" identified during interviews reveals a total loss of environmental security among older adults. When support trajectories are discontinuous, the resulting fear drives individuals toward extreme defensive behaviors, such as wearing anti-slip shoes while showering. This underscores the critical importance of "continuous support trajectories"—safety must evolve from isolated, individual grab bars toward a systemic defense that covers the entire workflow of movement.

Impact of De-labeling Design on Aging in Place

The "de-institutionalized aesthetics" emphasized in this study represents more than mere visual enhancement; it serves as a critical safeguard for the "self-efficacy" of older adults.

Through the concept of invisible assistive devices, we can effectively mitigate the labeling anxiety often triggered by conventional medical equipment. When design seamlessly integrates into daily life rather than highlighting functional impairment, older adults demonstrate a higher degree of autonomy and a greater willingness to lead independent lives.

Conclusion

Through situational observation and expert consultation, this study confirms that compensatory support behaviors—arising from the lack of professional grab bars in home bathroom environments—pose a high risk of falls for older adults. The findings reveal that washbasins and door frames are frequently misused as makeshift support points, reflecting significant "support gaps" within existing spatial layouts.

Based on these discoveries, this research proposes three core design principles: structural safety, behavior-oriented configuration, and de-institutionalized aesthetics. By integrating "reinforced platform-mounted washbasins" with "continuous support trajectories," these interventions provide intuitive and stable physical support while preserving the dignity of older adults through de-labeling design strategies.

In summary, bathroom safety should transcend the mere "addition" of assistive devices and instead focus on the "functional integration" of spatial equipment. The design guidelines proposed in this study provide an empirical foundation for future modifications of age-friendly housing and the development of related assistive products, ultimately realizing a vision of "aging in place" that is both dignified and secure.

Recommendations

While this study establishes a foundational framework for bathroom design guidelines, several areas warrant further investigation to enhance the safety of super-aged societies:

Expansion of Sample Diversity and Size

Due to the exploratory nature of this study, the sample was limited to three participants. Future research should recruit a larger and more diverse cohort, including older adults with varying levels of physical impairment (e.g., those using walkers or wheelchairs) to develop a more granular and tiered set of design standards.

Longitudinal Evaluation of Design Effectiveness

This study focuses on identifying behaviors and establishing design principles. Future research should evaluate the practical impact of "assistive-integrated" fixtures on reducing fall rates and enhancing user confidence through long-term utilization in home environments.

Cross-Cultural and Spatial Comparisons

Future studies could investigate how different cultural living habits and varied urban housing layouts (such as comparing high-rise apartments with traditional houses).

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Declaration of Generative AI and AI-Assisted Technologies in the Writing Process

The author declares that Google Gemini, OpenAI ChatGPT, and Google NotebookLM were used during the preparation of this manuscript.

- Google Gemini was utilized for conducting preliminary literature searches, information retrieval, and refining the academic prose for better flow and clarity.
- OpenAI ChatGPT was employed for the translation of specific draft sections from Chinese to English and for linguistic polishing to ensure terminological consistency.
- Google NotebookLM was used as a document analysis assistant to verify the internal logic of the research findings and to cross-verify the accuracy of cited literature sources.

The use of these AI-assisted technologies was strictly limited to linguistic refinement, translation, and the verification of existing research data. The author further declares that the core ideas, research design, experimental procedures, findings, data analyses, and discussions were originally conceived and derived from the systematic conduct of the research. The author has reviewed and edited the final output and accepts full responsibility for the integrity and accuracy of the manuscript's content.

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Analysis of Supportive Furniture Behaviors in Age-Friendly Residential Environments

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Abstract

Older adults often require additional support when performing daily activities such as standing up, sitting down, and posture transitions due to age-related declines in balance and muscle strength. However, the acceptance of medical-style handrails in residential environments remains low. In everyday life, older adults tend to intuitively rely on nearby household furniture as sources of support. This study employs scenario-based observation to examine the actual use of residential furniture as substitutes for handrail functions. The participants consisted of 5 older adults who were observed during sit-to-stand and posture transition activities in simulated daily living scenarios. The locations of support, types of furniture used, and modes of interaction were documented. In addition, expert questionnaire feedback was collected to evaluate the potential risks associated with using furniture as support. The results indicate that when performing sit-to-stand or posture transition activities near seating areas, older adults frequently used adjacent furniture, such as chair sides and table edges, as immediate support, thereby functioning similarly to handrails. These furniture elements were often selected due to their proximity and intuitive usability; however, their structural characteristics and dimensions are not specifically designed to provide support and may therefore pose potential safety risks. The findings reflect older adults' real-life residential behaviors and may serve as preliminary references for future age-friendly residential space planning and furniture-integrated assistive design.

Keywords: older adults, furniture support behavior, aging-in-place housing, usage behavior, aging society

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Introduction

Aging Trends

With the extension of average life expectancy and the continuous decline in birth rates in contemporary society, demographic structures have gradually shifted, making population aging a major global social issue. Taiwan is also expected to officially enter a super-aged society by 2026, bringing the maintenance of older adults' quality of life and healthy aging to the forefront of policy and academic concern. In response to the challenges posed by population aging, the World Health Organization has proposed concepts such as active aging, healthy aging, and aging in place, which have gradually become key objectives in aging-related policies and practical initiatives. These concepts emphasize enabling older adults to maintain independent living in familiar environments, delay functional decline, and ultimately realize the vision of aging in place.

Elderly Home Living Environment

As people age, older adults commonly experience physical and behavioral declines such as reduced muscle strength and diminished balance, which in turn affect the safety and stability of their activities of daily living. In Taiwan, the housing stock is generally characterized by an aging building profile, with many existing residential structures and facilities gradually deteriorating over time. As a result, the overall level of environmental support within the home is often insufficient to adequately respond to the living support needs that arise from age-related functional decline among older adults.

Furniture as Informal Support and Assistive Use

Assistive devices, which are commonly used as supportive tools for older adults, often present a medicalized appearance that leads to issues of stigmatization. This medicalized image may cause psychological reluctance among some older adults, thereby reducing their willingness to use such devices. Under these circumstances, furniture in everyday living environments gradually assumes the role of informal assistive devices. When appropriate support facilities are lacking within the home, older adults frequently rely on surrounding existing furniture as sources of support during daily activities, such as grasping table edges, chair backs, or cabinet edges to assist with posture transitions or to maintain bodily stability. However, these furniture elements are not originally designed for load-bearing or supportive purposes. Their structural forms, dimensional configurations, and load-bearing characteristics may therefore involve potential safety risks, yet they continue to be frequently used in daily life. This phenomenon warrants further investigation.

Research Purpose

Based on the aforementioned research background, this study aims to investigate the daily home-living behaviors of older adults through a scenario-based observation method, with a particular focus on their use of furniture as support during posture transitions. The study will identify furniture types that are most frequently relied upon for support and analyze their support locations, relevant dimensional characteristics, and modes of use. These findings will then be compared with the functional design principles and dimensional characteristics of handrails used in assistive devices. Finally, through expert evaluation, this study will examine the supportive potential, safety considerations, and potential risks of furniture when used as a

support interface, providing reference guidelines for subsequent furniture design for older adults and applications of assistive device–furniture integration.

Literature Review

Lifestyles and Behaviors of Older Adults

Aging-in-Place

In response to global population aging, the World Health Organization (WHO) has proposed concepts such as active ageing, healthy ageing, and aging in place, emphasizing the importance of maintaining functional ability and independent living in familiar environments (WHO, 2002; WHO, 2015; WHO, 2020).

In Taiwan, approximately 90% of older adults prefer to continue living in their original homes rather than relocate to institutional care facilities (Ministry of Health and Welfare, 2024), highlighting the importance of residential environments in supporting aging in place.

Daily Living Behaviors of Older Adults

Previous studies have indicated that the living room is one of the primary activity spaces for older adults and accommodates a wide range of daily behaviors (Cheng, 2018). In many residential environments, the living room and dining area are also spatially connected and represent major areas for daily activities.

As physical function declines with age, posture transitions and walking may become increasingly difficult, leading older adults to rely more on surrounding environmental elements for support during daily activities (Lee, 2006).

Residential Environments of Older Adults

Although homeownership rates among older adults in Taiwan remain high, many existing residential environments still lack sufficient environmental support for aging-related functional decline. Previous studies have indicated that aging housing conditions and residential spaces not originally designed for older adults may increase difficulties and safety risks during daily activities (Chen & Chang, 2023; Chung & Chou, 2021).

As physical function gradually declines with age, older adults may increasingly rely on surrounding environmental elements for support during daily movements and posture transitions (Hsieh, 2021).

Assistive Devices and Handrail Support

Assistive Devices

Previous studies have shown that assistive devices can improve safety, mobility, and functional performance among older adults (Chang, 2011). However, many assistive devices present a strong medical appearance, which may lead to psychological resistance and reduce willingness to use them (Mao, 2010).

Under these circumstances, household furniture may gradually function as an informal support interface in daily living environments. When formal assistive devices are unavailable or not preferred, older adults may rely on nearby furniture, such as table edges or chair backs, to assist with posture transitions and movement stability.

Handrail Support Characteristics

Handrails are regarded as important support interfaces for posture transitions and walking among older adults, helping improve movement stability and reduce fall risks (Tsai, 2018; Zheng, 2021). Compared to mobile assistive devices, handrails can provide immediate upper-limb support without significantly affecting circulation within residential spaces.

According to the Design Specifications for Accessible and Usable Buildings and Facilities (Ministry of the Interior, 2022), recommended handrail heights are generally between 75–85 cm. Appropriate dimensions and stable support conditions allow users to maintain effective grip and body support during movement and posture transitions.

Aging-Oriented Design and Assistive Furniture Integration

Based on the preceding discussion, conventional assistive devices may evoke psychological resistance due to their medical appearance, while existing residential environments often lack sufficient environmental support for older adults. Under these circumstances, furniture-integrated assistive design may provide supportive functions within familiar living environments while reducing the sense of medicalization (Cheng, 2018).

This design approach also responds to older adults' needs for low-intervention and high-support living assistance within familiar residential settings, serving as an important foundation for subsequent design development and research.

Methodology

This study employed scenario-based observation to examine furniture-based support behaviors among older adults in residential environments. The study focused on how older adults relied on surrounding furniture during posture transitions and daily movements.

After the observational analysis, expert evaluation was conducted to examine potential risks and related design considerations associated with furniture-based support behaviors.

Scope and Participants

This section defines the research participants and the scope of the study, clarifying the observational context and research boundaries that form the basis for subsequent scenario-based observation and data analysis.

Participants

The participants of this study are older adults aged 65 years and above who are able to live independently but experience partial functional decline. Individuals with severe disabilities or those who are long-term bedridden are not included in this study, as the research focuses on

older adults who are still capable of performing daily activities but may require environmental support during posture transitions or mobility.

Spatial Scope

This study was conducted within the residential environments of older adults, focusing on interactions between older adults and household furniture during daily activities and posture transitions.

Research Conditions

This study conducted a full-day scenario-based observation within the existing residential environments of older adults, documenting their daily activities and observing naturally occurring support behaviors under the condition that no formal medical assistive devices were used. This approach allows the study to capture how older adults rely on environmental support in real-life living situations.

Previous studies have indicated that the living room is the space where older adults spend the longest amount of time during the day, excluding sleeping periods. Observations in this study similarly showed that the living room was also the area where participants spent the most time during daily activities. In addition, many contemporary residential layouts adopt open-plan configurations in which the living room and dining area are spatially integrated.

Therefore, in the subsequent analysis, the living room and the combined living–dining area were selected as the primary observational scenarios for examining furniture-based support behaviors.

Scenario-Based Observation

This study employed scenario-based observation to document the daily behaviors of older adults in their residential environments. Through full-day observation, interactions between older adults and household furniture were recorded across different daily situations, with particular attention given to behaviors in which furniture was used as support during posture transitions or walking.

After organizing the observational data, frequently occurring furniture-based support behaviors were identified. Based on the furniture types and associated behavioral scenarios, representative furniture–behavior situations were selected as the analytical scenarios for subsequent expert evaluation.

Data Analysis

The observational data were organized and categorized for analysis based on furniture type, support interface, mode of support, and associated behavioral actions. Through this analytical process, frequently occurring furniture-based support behaviors were identified.

In addition, the observational data were statistically summarized. The height and spatial dimensions of support locations were further examined to illustrate the distribution of furniture use across different behavioral scenarios, providing a basis for subsequent expert evaluation and discussion.

Force Level Classification

Based on observational records of hand–interface interactions, force intensity was categorized into three levels:

Level 1 – Contact / Light Touch
Minimal contact without observable weight-bearing. The interface was lightly touched, primarily for balance confirmation or stabilization awareness.

Level 2 – Partial Support
Partial body weight was transferred to the support interface; however, it was not the primary force-bearing source. This level typically occurred during transitional assistance.

Level 3 – Weight-Bearing Support
The interface bore a substantial portion of body weight and functioned as the primary force-bearing source during posture transitions, often accompanied by clear downward pressing or pushing actions.

Expert Evaluation

After completing the scenario-based observation and preliminary data analysis, expert evaluation was conducted in this study. The evaluation adopted a scenario-based open-ended interview approach. Experts with relevant practical experience were invited to assess the furniture-based support behaviors identified in the observations, focusing on potential risks and possible improvement suggestions.

Expert Participants

The experts invited in this study were required to have professional backgrounds in interior design, construction engineering, or public facility planning in development companies, with more than ten years of relevant practical experience. The experts were expected to provide professional judgments from the perspectives of spatial design and architectural practice regarding older adults' support behaviors during posture transitions and the design conditions of supportive interfaces within residential environments. A total of three experts with relevant professional backgrounds were invited to participate in the interviews.

Evaluation Framework

The expert evaluation framework was developed based on the observational findings and preliminary data analysis of this study. The evaluation focused on furniture-based support behaviors actually used by older adults. Experts were asked to examine the scenarios from the following three perspectives:

1) Potential risks: whether using furniture as support may result in safety issues such as slipping, tipping, or loss of balance.
2) Sources of risk: factors that may lead to these risks, such as furniture structural stability, support height, material characteristics, or usage patterns.
3) Improvement suggestions: possible improvement directions related to furniture design or support positions.

Item Design and Evaluation Method

The expert evaluation was conducted using a scenario-based approach. High-frequency furniture-based support behaviors identified from the observational analysis were translated into specific scenarios and presented to the experts with accompanying illustrations and behavioral descriptions.

The interviews adopted an open-ended response format. Experts were asked to provide their professional opinions regarding potential risks, possible sources of risk, and improvement suggestions for each scenario. The interview content was recorded through audio recordings and written notes, and the collected responses were subsequently organized and analyzed to support the discussion and design implications of this study.

Results

This study documented furniture-based support behaviors among older adults in residential environments through scenario-based observation. A total of 148 support behaviors were recorded and analyzed according to furniture type, behavioral context, support mode, force level, and support interface characteristics.

Participants and Observational Data Overview

Five older adults with independent living ability but partial functional decline participated in this study. Scenario-based observation was conducted within their residential environments, including the living room, dining area, and bedroom.

The observations documented furniture types used for support, support locations, interaction modes, and associated behavioral situations during daily activities and posture transitions.

Distribution of Furniture-Based Support Behaviors

The distribution of furniture-based support behaviors is presented in Table 1.

Table 1
Distribution of Furniture-Based Support Behaviors

Furniture	Frequency (n)	Percentage (%)
Dining table	55	37.16
Sofa	41	27.70
Bed	37	25.00
Coffee table	6	4.05
Chair	6	4.05
Dining chair	3	2.03
Total	148	100

As shown in Table 1, dining tables, sofas, and beds accounted for the majority of observed support behaviors, representing 89.86% of all recorded interactions.

Distribution of Behavior Types

The distribution of behavior types in furniture-based support behaviors is presented in Table 2.

Table 2
Distribution of Behavior Types in Furniture-Based Support Behaviors

Behavior Type	Frequency (n)	Percentage (%)
Walking	39	26.35%
Sit-to-Stand	34	22.97%
Stand-to-Sit	27	18.24%
Seat Transfer	15	10.14%
Turning	12	8.11%
Lie-to-Sit	8	5.41%
Sit-to-Lie	7	4.73%
Lying Repositioning	4	2.70%
Changing Shoes	2	1.35%
Total	**148**	**100%**

As shown in Table 2, walking, sit-to-stand, and stand-to-sit were the most frequently observed behavioral scenarios.

Modes of Support and Force Characteristics

The distribution of support modes is presented in Table 3.

Table 3
Distribution of Support Modes in Furniture-Based Support Behaviors

Support Mode	Frequency (n)	Percentage (%)
Grip	8	5.41%
Press	83	56.08%
Pull	2	1.35%
Support	55	37.16%
Total	**148**	**100%**

As shown in Table 3, pressing was the most common support mode, followed by supportive holding.

The relationship between support mode and force level is presented in Table 4 and Table 5.

Table 4
Relationship Between Support Mode and Force Level (Frequency)

Support Mode	Level 3	Level 2	Level 1	Total
Grip	8	0	0	8
Press	74	9	0	83
Pull	2	0	0	2
Support	0	39	16	55
Total	**84**	**48**	**16**	**148**

Table 5
Percentage Distribution of Support Modes Across Force Levels

Support Mode	Level 3	Level 2	Level 1
Grip	9.52%	0%	0%
Press	88.1%	18.75%	0%
Pull	2.38%	0%	0%
Support	0%	81.25%	100%
Total	**100%**	**100%**	**100%**

The results indicate that high-force support behaviors were primarily associated with pressing actions, whereas low-force support behaviors mainly involved supportive holding.

Support Interface Height Characteristics

The height distribution of frequently used furniture support interfaces is presented in Table 6.

Table 6
Height Characteristics of Furniture Support Interfaces

Furniture	Support Interface	Height Range (cm)
Dining table	Table surface	75–85
Sofa	Seat surface	38–45
Sofa	Armrest	55–60
Bed	Bed surface	30–50
Coffee table	Table surface	50–55
Chair	Seat surface	30
Chair	Armrest	50

Overall, the heights of support interfaces involved in high-frequency support behaviors were distributed across different vertical ranges, suggesting that furniture elements of varying heights were used as support interfaces under different behavioral contexts.

Expert Evaluation of Furniture-Based Support Behaviors

Based on the preliminary behavioral observations, several common scenarios in which older adults relied on household furniture for support were identified. These scenarios served as the basis for the expert evaluation. The evaluation scenarios primarily focused on activities occurring in living room and dining areas, as these spaces represent major residential areas where older adults spend extended periods of time and frequently perform posture transitions during daily activities.

Scenario illustrations presenting different combinations of furniture types and behavioral actions were used to facilitate the expert evaluation. Experts from relevant fields were invited to review the scenarios and provide professional insights regarding the potential risks, sources of risk, and possible improvement strategies when furniture or spatial elements were used as support interfaces.

A summary of expert feedback regarding furniture-based support behaviors is presented in Table 7.

Table 7

Summary of Expert Feedback on Furniture-Based Support Behaviors

Element / Furniture	Behavior Scenario	Risk Source	Potential Risk	Design Improvement Suggestion
Chair	Sit-to-Stand	Seat height too low; insufficient armrest support; chair instability	Difficulty standing; chair sliding or tipping	Increase seat height; add stable armrests; improve stability
Sofa	Walking Support	Support height too low; difficult to grasp; discontinuous support surface	Unstable support during walking; loss of balance	Adjust support height; provide graspable armrest; continuous support surface
Sofa	Sit-to-Stand	Seat too low; cushion too soft; lack of armrests	Difficulty standing; forward imbalance	Add armrests; medium cushion firmness; adjust seat height
Sofa	Lie-to-Sit Transition	Backrest height insufficient; cushion too soft; insufficient support	Difficulty applying force; unstable posture	Adjust backrest height; medium cushion firmness; add support points
Coffee Table	Walking Support	Support height too low; glass surface too slippery; sharp edges	Hand slipping; collision injuries	Adjust height; anti-slip surface; rounded edges
Coffee Table	Stand-to-Sit	Uneven support height; slippery surface; sharp edges	Hand slipping; unstable support	Unify support height; anti-slip surface; rounded edges
Dining Table	Walking Support	Hard to grasp; insufficient stability; discontinuous support surface	Unstable support; collision risk	Provide graspable edge; improve stability
Dining Table	Sit-to-Stand	Furniture not designed for support; lack of graspable edge	Insufficient force application; collision risk	Add graspable edge; reinforce table stability; add assistive support

The summarized results indicate that furniture frequently used as support is mainly associated with structural stability, appropriate support height, and safe grasping interfaces.

The categorization of furniture-related design factors identified from expert feedback is presented in Table 8.

Table 8

Categorization of Furniture Design Factors Identified From Expert Feedback

Element / Furniture	Support Interface (Graspability / Height)	Furniture Dimension	Stability	Surface Friction	Edge Safety
Chair	✓	✓	✓		
Sofa	✓	✓			
Coffee Table	✓			✓	✓
Dining Table	✓		✓		✓

The results indicate that furniture-based support behaviors may be influenced by design conditions related to support interfaces, stability, and safety.

Discussion

In residential environments, household furniture may serve not only its original functional purposes but also act as a source of physical support during daily posture transitions for older adults. This phenomenon reflects the behavioral adaptation of older adults to their living environments, where nearby furniture is often used intuitively as support during movements such as standing up, sitting down, or maintaining balance while walking.

Because furniture is readily accessible and located along daily activity routes, older adults may naturally rely on these elements as convenient support interfaces when formal assistive devices such as handrails are not available.

Furniture as Informal Support in Residential Environments

The findings of this study suggest that household furniture may function as an informal source of support in residential environments for older adults. Observational results indicated that during daily activities, particularly posture transitions such as walking, sitting down, and standing up, older adults frequently relied on nearby furniture as immediate support. Furniture located in primary activity areas, such as sofas, dining tables, and beds, was often used as a convenient support interface due to its accessibility and proximity within the living environment.

This phenomenon reflects the behavioral adaptation of older adults to their surrounding environment. In situations where formal assistive devices such as handrails are not available, furniture located along daily activity routes may naturally become alternative support points. As a result, furniture within residential spaces may unintentionally provide supportive functions during movement and posture transitions, even though such supportive roles are not typically considered in conventional furniture design.

Handrail-Like Characteristics of Furniture Support

Another important finding of this study is that the dimensions of frequently used furniture support interfaces are similar to the typical height range of handrails. The measurement results indicated that many of the furniture edges used by older adults as support interfaces were distributed within a height range of approximately 55–85 cm. This range partially overlaps with the commonly recommended handrail height in residential environments.

This dimensional overlap suggests that certain furniture elements may unintentionally provide support conditions similar to those of handrails during daily posture transitions. When older adults perform movements such as standing up, sitting down, or maintaining balance while walking, furniture edges located within this height range may offer a convenient surface for hand contact and force application.

However, unlike handrails, household furniture is generally not designed specifically to support body weight or assist with balance during movement. Therefore, although furniture may exhibit handrail-like characteristics under certain conditions, its structural stability, surface properties, and edge design may not fully meet the safety requirements typically associated with dedicated assistive devices.

Design Risks of Furniture-Based Support

The findings of the expert evaluation further indicate that the safety of furniture-based support behaviors is influenced by several furniture design conditions. Experts pointed out that when household furniture is used as a support interface, potential risks may arise from factors such as support interface characteristics, furniture dimensions, structural stability, surface friction, and edge safety.

Unlike assistive devices that are specifically designed to support body weight and maintain balance, most household furniture is primarily designed for functional purposes such as seating, storage, or surface use. As a result, when furniture is unintentionally used as a support point during posture transitions, its structural properties and design features may not adequately accommodate the forces applied by the user.

These conditions may increase the potential risk of instability, slipping, or loss of balance during movement. Therefore, when considering furniture as a potential support interface in residential environments for older adults, design-related factors such as stability, surface texture, edge configuration, and dimensional suitability should be carefully evaluated.

Implications for Age-Friendly Furniture Design

The findings of this study indicate that older adults frequently rely on nearby household furniture as a source of physical support during daily activities. Therefore, in furniture design, in addition to considering the original functional purposes of furniture, it is also important to recognize the possibility that furniture may be used as support in actual use situations.

In particular, furniture elements located along daily activity routes, such as sofa edges and table edges, are often used as support interfaces during posture transitions. Incorporating supportive considerations into furniture design, such as appropriate height ranges, structural stability, safe edge configurations, and suitable surface friction, may help improve the safety and usability of residential environments for older adults.

Conclusion

This study explored how older adults rely on household furniture as support during daily activities in residential environments. Through behavioral observations and furniture measurements, the study identified common situations in which furniture was used as a support interface during posture transitions such as walking, sitting down, and standing up. The results indicated that furniture located near primary activity areas, particularly sofas and dining tables, was frequently used as a source of physical support.

The findings also revealed that the height of commonly used furniture support interfaces generally fell within a range of approximately 55–85 cm, which partially overlaps with the typical height range of handrails. This dimensional similarity suggests that certain furniture elements may unintentionally provide conditions suitable for hand support during daily movements.

However, expert evaluations indicated that the safety of furniture-based support behaviors may be influenced by several design-related factors, including support interface characteristics, furniture dimensions, structural stability, surface friction, and edge safety.

Since most household furniture is not originally designed to support body weight or assist with balance, these conditions may introduce potential safety risks when furniture is used as a support interface.

Based on the observational results and expert feedback, the potential risks associated with furniture-based support behaviors were further summarized according to behavioral scenarios and furniture types, as presented in Table 9. Corresponding design considerations are further discussed in Table 10.

Table 9
Potential Risks of Furniture-Based Support Behaviors by Scenario

Furniture	Behavior Scenario	Potential Risks
Chair	Sit-to-Stand	• Low seat height may increase sitting impact and make standing more difficult. • Lightweight furniture may slide when force is applied, reducing support stability.
Sofa	Walking Support	• Low support height and lack of graspable interfaces may reduce support effectiveness and affect walking stability. • Discontinuous support interfaces may lead to unstable support during walking.
Sofa	Sit-to-Stand	• Soft cushions or low seat height may increase the difficulty of standing and reduce stability. • The absence of armrests may reduce force application efficiency.
Sofa	Lie-to-Sit	• Overly soft cushions may provide insufficient support. • Lack of support interfaces may increase the difficulty of posture transitions.
Coffee Table	Walking Support	• Low support height, lack of graspable interfaces, and smooth surfaces may cause hand slipping or body imbalance. • Unprotected edges may increase collision injuries.
Coffee Table	Stand-to-Sit	• Low support height or slippery surfaces may reduce balance control during sitting. • Unprotected edges may increase injury risk during collision.
Dining Table	Walking Support	• Table edges may lack graspable interfaces, making it difficult to securely hold the furniture for support. • Insufficient structural stability may increase collision or imbalance risks.
Dining Table	Sit-to-Stand	• Lack of graspable edges may reduce effective force application. • Since the furniture is not designed for support purposes, force efficiency may be limited.

Table 10
Furniture Design Considerations for Supporting Older Adults

Furniture	Design Considerations
Chair	• Seat height should facilitate standing movements and reduce sitting impact. • Furniture stability and sufficient weight should prevent sliding when force is applied.
Sofa	• Appropriate seat height and cushion firmness should support posture transitions. • Armrests should be provided on both sides to offer symmetrical support and assist force application during posture transitions.
Coffee Table	• Graspable support interfaces may improve force application efficiency and body stability. • Anti-slip surfaces and rounded or protected edges may reduce slipping and collision injuries.
Dining Table	• Graspable support interfaces may facilitate temporary support. • Structural stability should prevent furniture movement when force is applied.

These design considerations highlight the importance of recognizing furniture as a potential support interface in residential environments. By incorporating such considerations into furniture and interior design, residential spaces may better support the safety and mobility of older adults and contribute to safer aging in place.

Declaration of Generative AI and AI-Assisted Technologies in the Writing Process

The author declares that ChatGPT (OpenAI), a generative AI tool, and translation software were used in proofreading, refining the language, and assisting with academic writing expression and reference formatting in accordance with APA style guidelines. The usage was limited to language translation, correcting grammatical and spelling errors, improving clarity and accuracy of statements, and organizing references.

The author further declares that these tools were not used to generate original research content. The ideas, design, procedures, findings, analyses, and discussion are originally written and derived from careful and systematic conduct of the research.

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Reimagining the Dining Area for Solitary Agers: Integrating Generative AI With Four Evidence-Based Design Principles

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Abstract

As Asian cities confront rapid population aging and an increasing number of older adults living alone, the home environment has become a critical site for supporting autonomy, emotional stability, and social connection. This study focuses on the dining area—an everyday setting where routines, relationships, and psychological rhythms converge—to examine whether a set of evidence-based age-friendly design principles (emotional comfort, safety-assured independence, community connectivity, and ability-adaptive design) can be effectively operationalized through human–AI collaboration. This study recruited 18 professional interior designers to generate AI-assisted spatial concepts embodying these four principles. Utilizing generative AI tools, participants produced a total of 432 images. Subsequently, three experts in gerontology and design evaluated the outputs using a structured rubric aligned with the principles to assess the feasibility and appropriateness of the proposed solutions. Follow-up semi-structured interviews explored how designers interpreted the diverse needs of older adults, negotiated design constraints, and navigated the relationship between professional judgment and AI-generated suggestions. Emotional comfort received the highest mean rating *(M = 5.91)*, while ability-adaptive design received the lowest *(M = 4.31)*. Findings reveal both the potential and limitations of generative AI in translating age-friendly principles into actionable spatial strategies. While AI accelerates visualization and supports broader concept exploration, it also exposes cultural and contextual gaps—particularly regarding safety, daily routines, and social norms in Asian households. This study provides preliminary empirical grounding for human–AI collaborative design in domestic dining environments, and outlines considerations for future aging-in-place research.

Keywords: generative AI, age-friendly design, dining environment, older adults, interior design

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Introduction

Improvements in medical care and living conditions have contributed to increased life expectancy, while declining fertility rates have accelerated the demographic shift toward an aging population (Nakatani, 2023). In recent years, Asian societies have been experiencing rapid population aging. Within this context, a growing number of older adults are choosing to live independently in urban environments, leading to a continuous rise in single-person households and posing new challenges for residential design and social policy (Jian et al., 2025). Consequently, how residential environments can support older adults' daily activities, emotional well-being, and social participation has become an increasingly important issue in both design research and public policy.

Against this backdrop, the concept of age-friendly design has gained increasing attention in both research and policy domains. This concept emphasizes reducing environmental barriers that older adults may encounter in their daily lives through thoughtful design, while supporting their ability to live independently. Previous studies have indicated that well-designed residential environments can enhance safety, promote autonomy, and improve the psychological well-being and overall quality of life of older adults (Cha, 2025). For older adults living alone, shared meals represent important moments for communication and emotional connection among family members, and the dining environment may influence their daily routines and sense of belonging at home.

Shared meals are not only related to nutrition and physical health, but are also closely associated with emotional experiences and social interaction (Song et al., 2025). As the demand for aging in place continues to grow, in addition to existing research focused on healthcare environments, the configuration of everyday domestic dining spaces has gradually become a key concern in the design field.

Meanwhile, generative AI is increasingly influencing design practices. It enables designers to efficiently explore a wide range of design possibilities and to generate conceptual images and spatial proposals based on textual prompts (Chen et al., 2025). However, prior work has also documented that image-generation models reproduce aesthetic and cultural biases embedded in their training data, and that they often underrepresent assistive or accessibility-related features (Liang & Cai, 2025). Accordingly, there is a growing need to examine whether AI-generated designs can adequately address the complex, human-centered needs associated with older adults' daily lives.

This study takes the domestic dining environment as its research context and evaluates the feasibility and effectiveness of AI-assisted design based on four principles: emotional comfort, safety-assured independence, community connectivity, and ability-adaptive design.

Based on the above background, this study addresses the following research questions:

RQ1: How do AI-assisted design proposals differ in their performance across the four age-friendly design principles?

RQ2: How do designers interpret and translate the four age-friendly design principles into prompts?

RQ3: What limitations of AI-generated design outputs are identified by expert evaluators?

Literature Review

Age-Friendly Design Principles

With the rapid aging of the global population, the concept of age-friendly environments has received increasing attention in both design research and public policy. Age-friendly design aims to create environments that support older adults' independence, safety, and well-being, while responding to changes in their physical, cognitive, and social capacities (Jian et al., 2025).

Within this context, the concept of aging in place emphasizes that older adults should be able to continue living safely and comfortably in familiar residential environments, while maintaining social relationships and a sense of identity. Accordingly, age-friendly environments must address not only accessibility and safety, but also psychological comfort and opportunities for social interaction.

Building on this perspective, a study on the residential environments of older adults living alone in Thailand found that multiple environmental factors influence their psychological health and quality of life, highlighting the need for residential design to address both physical and psychosocial needs. The study further proposed four age-friendly design principles: emotional comfort, safety-assured independence, community connectivity, and ability-adaptive design (Kititarakul, 2025). Although this framework was developed in a Bangkok context, its four dimensions align with widely used aging-in-place criteria and are applicable to comparable urban Asian settings; limitations of this cross-context transfer are discussed in the Limitations section.

Emotional comfort refers to environments that provide psychological ease, familiarity, and a sense of security, helping to reduce loneliness and anxiety among older adults. Safety-assured independence emphasizes minimizing environmental risks while supporting older adults' autonomy and decision-making in daily life. Community connectivity focuses on whether a space facilitates interaction with family members, neighbors, or the broader community, thereby preventing social isolation. Ability-adaptive design refers to the flexibility of environments to accommodate changes in older adults' physical mobility or cognitive abilities.

These four principles provide an important conceptual framework for understanding how residential environments influence the quality of life of older adults. In this study, they serve as the core criteria for design evaluation, used to examine whether design outcomes generated through collaboration between generative AI and professional designers can effectively respond to the needs of the aging population.

Domestic Dining Environment and Aging

Among the various spaces within the home, the design of the dining area influences not only physical comfort but also social interaction and emotional experience in the daily lives of older adults. Eating is not merely a basic physiological necessity; it is also an important social and communicative activity. Shared meals with family members often serve as key moments for daily interaction and emotional bonding, while also helping to maintain a regular daily routine. Typically located between the kitchen and the living room, the dining area frequently functions as a central space for everyday family interaction (Sal Moslehian et al., 2023).

Accordingly, the spatial circulation, furniture arrangement, and environmental conditions all affect whether older adults can independently participate in dining activities (Wang et al., 2022). In addition, factors such as table height, seating comfort, and lighting conditions play a critical role in ensuring safety and ease of use during meals.

Within the field of age-friendly design, relatively limited attention has been given to domestic dining environments, and even fewer studies have examined how generative AI tools might support their design. Most existing studies have focused on healthcare facilities, long-term care settings, or broader residential issues (Wang et al., 2022). In comparison, given the close relationship between daily activities and spatial environments, investigating how domestic dining spaces can support older adults' independent living and social interaction holds significant research value.

Generative AI in Design Practice

Generative AI is capable of rapidly producing visual concepts, spatial configurations, and multiple design alternatives based on textual prompts or predefined parameters (Li et al., 2025). Such technologies have been widely applied across fields including architecture, interior design, and product design, particularly during the early stages of concept development and creative exploration.

By enabling the rapid generation of diverse design possibilities, generative AI assists designers in exploring different spatial configurations and design directions (Li et al., 2025). In most contexts, AI does not replace designers; rather, it functions as a supportive tool that facilitates creative development and iterative exploration throughout the design process (Wang et al., 2025). Within this human–AI collaborative framework, designers are still required to evaluate, refine, and reinterpret AI-generated outcomes based on user needs and contextual conditions.

However, some studies have also identified limitations in AI-assisted design. While generative AI can produce visually appealing outputs, it still faces challenges in understanding complex human needs, social relationships, and cultural contexts (Liang & Cai, 2025). Image-generation models in particular are known to reflect the distribution of their training data, which may overrepresent Western residential aesthetics and underrepresent assistive devices, grab bars, or wheelchair-accessible circulation. These limitations are particularly evident in age-friendly design scenarios, where the needs of older adults involve multiple dimensions, including emotional well-being, social interaction, and cultural background.

As the application of generative AI in design continues to expand, its collaborative role with designers in age-friendly design contexts has begun to attract increasing attention. Whether AI-generated design outcomes can adequately respond to established, human-defined age-friendly design principles and align with actual user needs remains an open question. Therefore, this study adopts emotional comfort, safety-assured independence, community connectivity, and ability-adaptive design as key prompts to generate multiple design concepts, which are subsequently evaluated by experts to examine the effectiveness of these four principles.

Methodology

Research Design

This study adopts a mixed-methods approach, combining quantitative expert evaluation and interviews to examine how the process of generative AI-assisted design translates four age-friendly design principles into concrete spatial design solutions.

All participating designers and experts provided written informed consent prior to participation. The research process consists of three main stages. First, interior designers were invited to use generative AI tools to produce spatial design proposals based on the four age-friendly design principles. Subsequently, experts in aging and design-related fields were invited to conduct quantitative evaluations of the design proposals. Finally, semi-structured in-depth interviews were conducted to collect experts' assessments and perspectives on the design outcomes, in order to further understand the potential and limitations of AI-assisted design.

By integrating quantitative evaluation and qualitative interview data, this study enables a comprehensive analysis of AI-assisted collaborative design in age-friendly environments from both outcome- and process-oriented perspectives.

Task Design

This study recruited 18 interior designers with professional backgrounds and practical experience in spatial design to develop design proposals for domestic dining environments for older adults living alone. The participants exhibited varied levels of professional experience, with most having ≤ 5 years of experience (n = 15) and the remainder having > 15 years (n = 3). Participants were recruited through professional networks and academic referrals within the fields of interior design and spatial design. The sample consisted of 6 male and 12 female designers. In addition, prior experience with generative AI tools was documented, with 94.4% of participants reporting previous use of generative AI in their design practice. The design task aimed to examine how generative AI can assist designers in translating age-friendly design principles into concrete spatial design concepts.

All designers were required to use the same generative AI tool, Google Gemini (Nano Banana image generation model, accessed February 2026), to produce visual representations of indoor dining spaces. Each designer generated 24 design images to ensure sufficient variation across design proposals.

To ensure comparability among different design cases, standardized constraints were applied to the design scenarios. All generated images were required to meet the following conditions: the space type was a residential dining area; the cultural context was an urban Asian residential environment; the target users were older adults aged 65 and above who live alone; and the space was intended for daily meals and basic social interaction. All images were to be presented in an interior perspective view.

During the generation process, designers were required to write prompts in Mandarin and maintain a consistent design style throughout their outputs. In addition, designers were encouraged to incorporate descriptive terms related to spatial atmosphere and emotional experience in their prompts to enhance contextual expression.

Designers were instructed to incorporate four age-friendly design principles into their prompts: emotional comfort, safety-assured independence, community connectivity, and ability-adaptive design. These principles served not only as key inputs in the design generation process but also as the primary criteria for subsequent expert evaluation.

Across the 24 generated images, designers were able to explore a range of design variations, including different levels of safety support, diverse dining interaction scenarios, varying degrees of openness between kitchen and dining areas, and the adaptability of the space to future assistive devices or changes in physical abilities.

Upon completion of the task, participants submitted the full set of prompts along with the generated images. These materials served as the primary data for subsequent expert evaluation and research analysis.

Expert Evaluation

Upon completion of the design task, all design proposals were evaluated by a panel of three expert reviewers. The experts were adjunct instructors with professional backgrounds in interior design and architecture, combining both academic and industry expertise. In addition to their academic roles, all experts had substantial professional experience, with one having 6–15 years of practice and the other two having over 15 years of experience. All experts were also familiar with generative AI tools, ensuring their ability to critically evaluate AI-assisted design outcomes.

Following the evaluation, the experts participated in in-depth interviews. Their involvement ensured that the assessment incorporated both design expertise and perspectives on the needs of older adults. The primary aim of the expert evaluation was to examine whether the spatial design solutions generated through AI-assisted design effectively reflect established age-friendly design principles.

The experts evaluated each design proposal based on four principles: emotional comfort, safety-assured independence, community connectivity, and ability-adaptive design. A 7-point Likert scale was employed (1 = very poor, 7 = very good) to assess the extent to which the AI-generated designs responded to these age-friendly design principles.

To support construct validity and ensure consistency in evaluation, anchor descriptions were provided for key points on the scale (scores of 1, 4, and 7). A score of 1 indicated that the design failed to address the principle, 4 indicated a moderate or partial representation, and 7 indicated a strong and well-integrated representation of the principle within the spatial design. Experts were instructed to evaluate each principle based on observable spatial features, such as layout, furniture configuration, environmental qualities, and adaptability to user needs.

To minimize potential bias, the three experts conducted their evaluations independently and were blinded to designer identity. To examine the consistency of ratings across the three experts, pairwise Pearson correlations were calculated for each design principle, and the mean absolute difference between experts was reported. The unit of analysis was the designer-level mean across the 24 images each designer produced (n = 18).

Expert Interviews

Following the completion of the expert evaluation, semi-structured interviews were conducted with the same group of experts. Each interview lasted approximately 50 minutes and was conducted either in person or via online video conferencing, depending on the availability of the participants.

The purpose of these interviews was to gain deeper insights into the criteria underlying the experts' evaluations. The interview content focused on several aspects, including the design factors considered during the rating process, the experts' understanding of older adults' spatial needs, and their perspectives on the strengths and limitations of generative AI in the design process. In addition, the interviews explored whether AI-generated design solutions can adequately respond to the cultural and social contexts of older adults.

All interviews were conducted individually and were audio-recorded with informed consent from the participants. The interview data provided qualitative insights to support the interpretation of the quantitative results and to further understand how experts interpreted the design proposals.

Data Analysis

This study analyzes two types of data: quantitative evaluation data from expert ratings and qualitative data from in-depth interviews. These two datasets were first processed and analyzed separately and are presented in the subsequent sections.

Given the modest sample size (n = 18 designers), the quantitative data were analyzed primarily using descriptive statistics (means, standard deviations, minimum, and maximum) for each of the four design principles. Inter-rater agreement among the three experts was examined using Pearson correlation coefficients. Because the study is exploratory and the sample is small, no inferential significance testing was conducted; observed differences across principles are therefore described, not tested.

The qualitative data were derived from the in-depth interviews conducted after the expert evaluation. The interview transcripts were reviewed and organized to identify key themes regarding the experts' observations of the design proposals and the AI-assisted design process. The analysis focused on how experts assessed the extent to which the designs responded to the needs of older adults, as well as the design considerations and limitations encountered when using generative AI.

The findings from the qualitative analysis are presented alongside the quantitative results in the Results section to provide a more comprehensive interpretation of the study outcomes.

Results

This study included 18 sets of AI-assisted design proposals for domestic dining environments, which were evaluated by expert reviewers. All design proposals were generated based on the four age-friendly design principles and were assessed by three experts with backgrounds in gerontology and design.

Descriptive Statistics

Table 1

Descriptive Statistics of Four Age-Friendly Design Principles

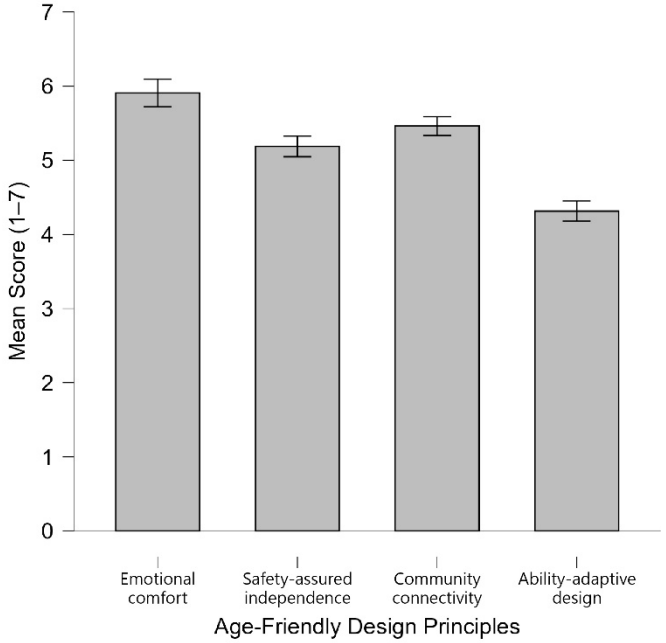
Principles	Emotional comfort	Safety-assured independence	Community connectivity	Ability-adaptive design
Mean	5.91	5.19	5.46	4.31
Std. Deviation	0.30	0.54	0.29	0.54
Minimum	5.33	4.00	5.00	3.33
Maximum	6.33	6.00	6.00	5.33

Note. Scores are based on a 7-point Likert scale (1 = very poor, 7 = very good).

Consistency across the three experts was examined using pairwise Pearson correlations and mean absolute differences. Across the four design principles, pairwise correlations ranged from r = -0.49 to r = 0.55, and the mean absolute difference between any two experts was less than 1.5 points on the 7-point scale. These findings suggest modest consistency among experts in this exploratory study, while also reflecting individual variation in how each principle was interpreted.

Figure 1

Mean Expert Ratings of the Four Age-Friendly Design Principles



Note. Error bars represent standard deviation.

Overall, the expert evaluation results indicate that the AI-assisted design proposals received generally positive ratings across the four age-friendly design principles. Three of the principles achieved mean scores above 5, suggesting that most design proposals demonstrated adequate responsiveness to age-friendly design considerations.

Among the four principles, emotional comfort received the highest mean score *(M = 5.91, SD = 0.30)*, followed by community connectivity *(M = 5.46, SD = 0.29)*, and safety-assured independence *(M = 5.19, SD = 0.54)*. Ability-adaptive design received the lowest mean score *(M = 4.31, SD = 0.54)*.

Comparison Across Design Principles

The descriptive statistical results indicate that there are notable differences in how the age-friendly design principles are reflected in the AI-generated design proposals.

The high rating for emotional comfort suggests that many AI-generated designs successfully create comfortable and visually appealing spatial atmospheres, for example, through the use of lighting, materials, and overall spatial composition to evoke emotional resonance. This finding indicates that generative AI demonstrates particular strengths in expressing visual ambiance and spatial experience.

“I think emotional comfort is related to color, lighting, and even the tone of the images. Warmer tones tend to make you feel more at ease.” (Expert 1)

Similarly, community connectivity also received relatively high ratings *(M = 5.46, SD = 0.29)*, suggesting that some design proposals effectively promote social interaction through features such as open-plan kitchen–dining layouts, shared dining tables, and interactive spatial configurations.

However, ability-adaptive design received the lowest mean rating among the four principles (M = 4.31, SD = 0.54), suggesting that AI-generated designs were less consistent in addressing the long-term needs of older adults. In particular, design strategies related to changes in physical abilities, the use of assistive devices, or future spatial adaptability were not clearly represented in some proposals.

“I think having a kitchen island takes up a lot of space. For older adults with reduced mobility, they would have to walk around it, which makes the space less usable.” (Expert 2)

“Due to ergonomic considerations, some Japanese-style designs may feel comforting, but they are not practical for older adults—the distances between tables and kitchen elements are not suitable for users with limited mobility.” (Expert 3)

The difference in mean scores between emotional comfort and ability-adaptive design further suggests that different age-friendly design principles may vary in their degree of translatability within the AI-assisted design process.

Score Distribution and Design Variability

The distribution of ratings indicates that the degree of variation differs across the four design principles.

The relatively small standard deviations for emotional comfort *(SD = 0.30)* and community connectivity *(SD = 0.29)* suggest a high level of agreement among experts in their evaluations of these two principles. This implies that most AI-generated designs demonstrate a consistent level of performance in terms of spatial atmosphere and interactive environments.

In contrast, safety-assured independence *(SD = 0.54)* and ability-adaptive design *(SD = 0.54)* show greater variability, indicating that the extent to which these principles are reflected varies more substantially across design proposals.

Notably, for ability-adaptive design, the scores range from 3.33 to 5.33, suggesting that while some design proposals incorporate a certain degree of adaptive design considerations, others exhibit limited inclusion of such strategies.

Discussion

This study employed expert evaluation and in-depth interviews to examine whether collaboration between generative AI and designers can effectively address four age-friendly design principles in domestic dining environments: emotional comfort, safety-assured independence, community connectivity, and ability-adaptive design.

The findings indicate that, in terms of emotional comfort, AI-generated designs are more capable of representing design elements related to spatial atmosphere. Such features can be readily expressed through image generation, making it easier to produce concrete design outcomes associated with emotional experience and environmental ambiance. This pattern is consistent with the findings of (Chen et al., 2025), who report that current generative image models excel at surface-level aesthetic qualities—lighting, material, color—while being weaker on functional or constraint-driven features.

Regarding safety-assured independence, experts noted that AI-generated designs can offer diverse spatial concepts, providing new perspectives for design exploration. However, their practical application in real residential settings still requires careful consideration of factors such as spatial dimensions, furniture configuration, and circulation within the living environment.

In terms of community connectivity, older adults' lifestyles and patterns of family interaction often vary significantly, and these contextual factors are not always fully captured in AI-generated designs. Therefore, the implementation of age-friendly design still requires the integration of professional design expertise and an understanding of local living contexts.

As for ability-adaptive design, the needs of older adults often involve more complex usage scenarios and long-term living requirements. These considerations are difficult to fully represent through image generation alone, indicating that professional design input and contextual analysis remain essential in the design translation process. One plausible explanation is that Nano Banana's training distribution overrepresents stylized residential interiors and underrepresents assistive devices such as grab bars, anti-slip flooring, or wheelchair-accessible circulation; this is consistent with (Liang & Cai, 2025) observation that generative models often underrepresent accessibility features. Future work could test this hypothesis by systematically comparing prompts with and without explicit assistive-device vocabulary.

"While AI can certainly generate designs, the judgment required to interpret user needs still needs to be carried out by designers at this stage." (Expert 2)

Limitations

First, the sample consists of 18 interior designers and three expert raters. While this is adequate for an exploratory descriptive study, it limits the statistical power for comparative inference. Accordingly, no inferential testing was conducted, and all cross-principle comparisons are interpreted as descriptive.

Second, the four age-friendly design principles were originally derived from a study conducted in Bangkok, Thailand (Kititarakul, 2025). Although these principles are conceptually applicable to other urban Asian settings, their operationalization may vary across cultural contexts. The present study does not explicitly examine such cross-cultural variation.

Third, the study employed a single generative AI tool (Google Gemini, Nano Banana image generation model) accessed within a specific time frame. As generative models are continuously updated, the exact outputs observed in this study may not be fully reproducible in future versions.

Fourth, prompts were written in Mandarin Chinese, and the design outputs were evaluated within the context of urban Asian residential environments. Therefore, the generalizability of the findings to other languages, cultural contexts, or housing typologies remains limited.

Fifth, expert evaluation was based solely on visual image outputs and did not include physical mock-ups, virtual reality walkthroughs, or feedback from end users (older adults). Future research should incorporate older adults as evaluators to better capture user-centered perspectives.

Conclusion

This study explored the application of collaboration between generative AI and designers in the design of age-friendly domestic dining environments, and examined how age-friendly design principles are translated within AI-assisted design processes. The findings indicate that generative AI demonstrates significant potential in design exploration and the expression of spatial atmosphere, enabling designers to efficiently generate diverse design concepts. However, when addressing issues related to older adults' long-term living needs and spatial functionality, professional judgment from designers remains essential.

The results also highlight that, within the context of aging societies in Asia, cultural and lifestyle factors play a critical role in shaping age-friendly spatial design. Overall, this study provides preliminary empirical evidence that, in the specific context of domestic dining environments, generative AI offers stronger support for emotional and social dimensions of age-friendly design than for ability-adaptive considerations. Building on this finding, future work should (a) extend the sample to include end users themselves, (b) test whether explicit assistive-device prompt vocabulary narrows the observed gap, and (c) examine cross-cultural variation across urban Asian contexts.

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Declaration of Generative AI and AI-Assisted Technologies in the Writing Process

In the writing process of this manuscript, ChatGPT (OpenAI, GPT-5.3; accessed March 2026) was used as an AI-assisted language tool. Its use was limited to translation, grammar correction, and improving clarity and academic expression.

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Later-Life Re-employment Pathways: A Life-Course Narrative Review of Taiwan and Japan

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Abstract

This study conducts a narrative review grounded in a life-course perspective to examine how Taiwan and Japan structure divergent policy pathways for older adults' re-employment. Drawing on legislative documents, government reports, and academic literature, the review analyzes how institutional arrangements shape late-career transitions across the life span. Japan's mandate-driven system produces a highly standardized pathway. The legally required extension of employment to age 70 establishes a universal transition at age 60, yet it often results in a noticeable “salary cliff” and occupational downgrading. These mechanisms reorganize late-life work trajectories in ways that limit individual agency. In contrast, Taiwan's incentive-based model generates a fragmented and stratified pathway. Re-employment opportunities largely depend on individual's accumulated human and economic capital, allowing high-skilled older workers to continue with greater flexibility, while low-skilled workers face more precarious exits. This pattern reinforces cumulative disadvantages over the life course. Overall, despite their contrasting institutional logics—state-directed in Japan and market-oriented in Taiwan—both models reflect a tension between regulation and limited support. A life-course perspective highlights how current policies do not fully enable self-determined and dignified late-life work trajectories. Future policy development should move beyond narrow labor-utilitarian objectives to promote meaningful and equitable pathways for older adults.

Keywords: social investment, life-course perspective, older adult re-employment, policy comparison

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Introduction

Population aging presents profound challenges to labor supply, pension sustainability, and social welfare systems in East Asia. Japan has entered the "super-aged" stage with over 29% of its population aged 65 and above, while Taiwan is projected to reach this threshold by 2025 (Ministry of Health and Welfare, Taiwan, 2022; Shen, 2024). These demographic shifts have prompted both countries to seek policy responses to address labor shortages and pension financial pressures.

In response, both countries have shifted from viewing older adults as welfare dependents to recognizing them as valuable human resources. This shift aligns with the rise of the social investment paradigm, which advocates for social policies that move from post-hoc compensation to proactive capability building, aiming to enhance citizens' employability and economic self-sufficiency (Hemerijck, 2011; Wu, 2020). Applying social investment logic to aging societies has generated policies centered on "productive aging" aimed at extending working lives and activating older human resources (Tung, 2024).

Despite facing similar demographic pressures, Taiwan and Japan have developed markedly different institutional logics for promoting older adult re-employment. Japan has established a mandate-driven system centered on the Act on Stabilization of Employment of Elderly Persons, legally requiring firms to secure employment for employees up to age 70. Taiwan, by contrast, has adopted an incentive-based model under the Middle-Aged and Older Persons Employment Promotion Act, using subsidies and job redesign grants to encourage voluntary firm participation (Ho & Wang, 2024; Ma & Yu, 2024).

Existing research has largely evaluated these policies through the lens of labor participation rates or economic efficiency. However, this paper argues that such assessments are insufficient. Drawing on Kvist's (2016) life-course framework, this study contends that an individual's capacity for dignified re-employment in later life is shaped by their educational, occupational, and family trajectories. Policies that ignore this continuity may inadvertently reinforce existing inequalities (Anxo et al., 2010).

Therefore, this narrative review addresses three research questions: (1) How do social investment principles shape the policy goals and instruments in Taiwan and Japan? (2) What are the distributive consequences of these "mandate-driven" and "incentive-based" models? (3) How can a life-course perspective inform future policy design?

Theoretical Framework: Social Investment and Life-Course Perspectives

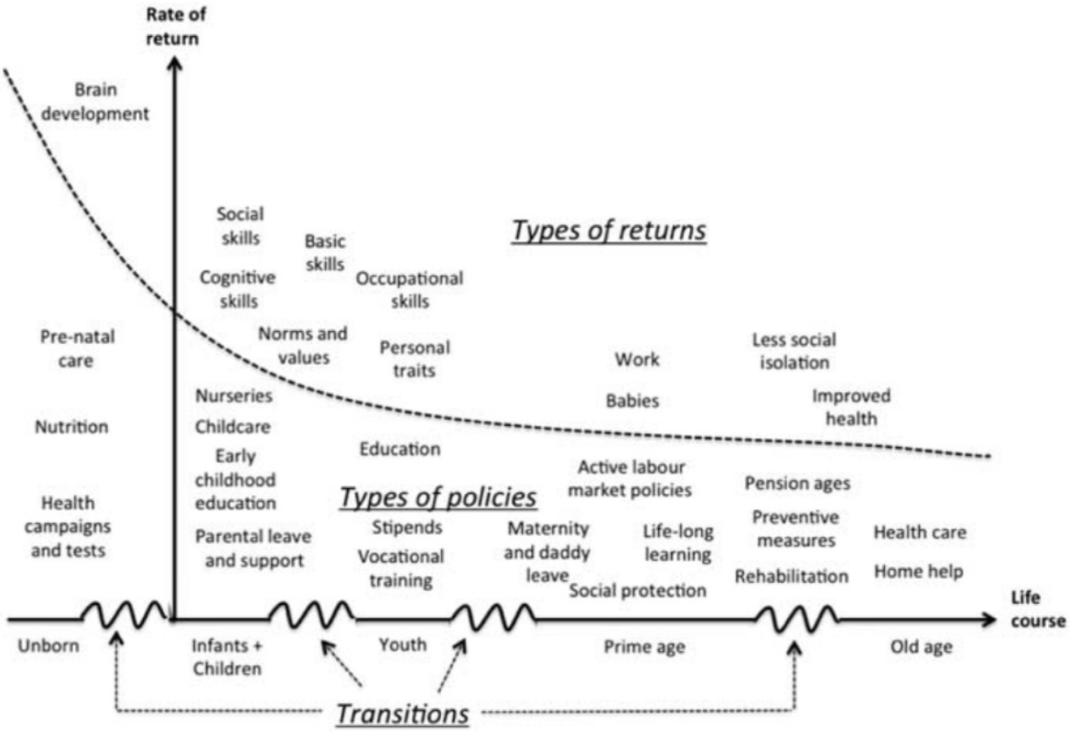
The social investment perspective emerged in the 1990s as a response to the limitations of both Keynesian welfare expansion and neoliberal retrenchment. Hemerijck (2011) characterizes it as an evolving paradigm that emphasizes "preparation" over "repair," viewing social expenditures as investments in human capital that yield long-term returns. Applied to aging societies, this logic reframes older adults as assets with productive potential, justifying policies that extend working lives.

Kvist (2016) advanced this framework by integrating a life-course perspective, arguing that effective social investment must transcend fragmented, stage-specific interventions. He identifies three critical life stages—early, mid, and late—and emphasizes that policy investments must be continuous and cumulative across these stages. Late-life employability,

from this perspective, reflects the long-term interplay of education, occupational history, family roles, and health capital (Anxo et al., 2010).

Figure 1

Kvist's Life-Course Social Investment Framework



Note. From Kvist (2016).

This framework provides the analytical lens for this study, enabling an examination of how Taiwan's and Japan's re-employment policies interact with individuals' differentiated life trajectories.

Japan's Mandate-Driven System: Standardization With Stratification

Japan's approach to older adult re-employment is built upon state intervention and legal mandates. The Act on Stabilization of Employment of Elderly Persons requires firms to choose among three options: raising the retirement age, abolishing the retirement system, or introducing a continued employment system. Through successive legal revisions, Japan has developed a highly standardized older worker trajectory centered on age 60 as a critical transition point (Jiang, 2023).

This mandate-driven system can be understood as an extension of Japan's traditional “lifetime employment” regime. However, this regime historically covered only about 20% of the labor force, predominantly male employees in large corporations (Ono, 2010). Under seniority-based wage structures, older workers command high personnel costs. In response to legal requirements, most firms implement “re-employment systems” that retain workers past retirement but with significant adjustments to position and compensation (Nichol et al., 2022).

Empirical research reveals the consequences of this approach. Over 80% of companies set the retirement age at 60 and rehire workers through re-employment mechanisms, with approximately 60% of rehired workers transitioning to non-regular positions with substantially

reduced wages. About 55.4% of men aged 60–64 face wage reductions upon re-employment, with over half experiencing cuts exceeding 40% (Jiang, 2023). Kodama (2015) found that approximately 34.8% of rehired workers receive wages only 60–70% of their pre-retirement levels.

Japan's employment policies have undergone multiple revisions. The 2006 amendment first imposed the three-choice obligation on firms but retained employer discretion in selecting workers. The 2013 amendment further eliminated this selection mechanism, requiring unconditional continued employment until age 65 while allowing transfers to subsidiaries or affiliated companies (Jiang, 2023). Li (2021) notes that workers aged 60 and above in Japan work an average of 4.5 days per month with monthly wages of 189,000 yen, while those aged 65 and above work 3.9 days with wages of 168,000 yen.

Research by Yoonseock (2015) indicates that whether older adults can maintain the same occupation after retirement critically determines their wages. Wels and Takami's (2021) longitudinal research reveals that the transition from regular to non-standard employment significantly damages mental health due to wage cuts, status demotion, and job insecurity. Minami et al. (2016) studied Tokyo's employment support center and found that its clients were predominantly older adults with lower education and income seeking employment due to economic necessity.

From a life-course perspective, Japan's mandate-driven system produces a paradoxical outcome. While successfully maintaining high labor participation rates, it operates through mechanisms that may limit individual agency and restructure late-life work trajectories in ways that diminish job quality. The system emphasizes continued utilization of existing human capital rather than investment in new capabilities during late career (Debroux, 2016).

Taiwan’s Incentive-Based System: Flexibility With Fragmentation

In contrast to Japan, Taiwan has developed an incentive-based model characterized by market-oriented governance. The Middle-Aged and Older Persons Employment Promotion Act, enacted in 2020, provides employment subsidies, job redesign grants, vocational training, and employment matching services. The core logic is to encourage voluntary firm participation through financial incentives (Ho & Wang, 2024; Ma & Yu, 2024).

In response to population aging, Taiwan introduced the “55Plus Employment Promotion Measures” in 2024 and amended the Labor Standards Act to explicitly allow labor-management negotiation to extend the mandatory retirement age (Chung, 2025). Ho and Wang (2024) note that the Act encompasses six dimensions: prohibiting age discrimination, stabilizing current employment, promoting re-employment for the unemployed, supporting post-retirement re-employment, silver talent services, and employment opportunity development.

Taiwan's approach can be characterized as a “selective social investment” model. Research indicates that policy benefits tend to accrue to those with existing learning capacity and resources. Lee and Wang (2025) found that successfully reemployed middle-aged and older adults actively utilize government-provided vocational training and informal learning to enhance their competitiveness. Those lacking such capacities are more likely to be excluded from policy benefits.

The distributive consequences of this model are significant. According to Taiwan's Ministry of Labor (2023), among approximately 5 million middle-aged and older employed persons, 69% are concentrated in low-skilled occupations, while only 31% hold high-skilled positions. Gender disparities are evident, with men predominantly working as production operators and laborers, while women are concentrated in service and sales roles. Furthermore, 76.8% of workers in agriculture, forestry, and fishing are middle-aged or older.

Taiwan's labor participation rates for older adults lag significantly behind Japan's—only 9.2% for those aged 65 and above compared to Japan's 25.6% (Ministry of Labor, 2023). This gap reflects multiple factors: relatively sufficient wealth accumulation enabling early retirement, persistent age discrimination, and the relatively recent implementation of active aging policies (Tung, 2024). Even after legislation, limited awareness of policies among firms and workers undermines effectiveness (Ma & Yu, 2024).

Table 1

International Comparison of Labor Force Participation Rates by Age Group (2021, %)

Age Group	Taiwan	South Korea	Singapore	Japan	United States
45–49	84.4	79.9	88.3	88.5	82.2
50–54	75.4	79.3	84.8	87.5	79.2
55–59	58.9	74.8	77.7	84.2	72.2
60–64	38.6	62.2	65.9	73.8	57.0
65+	9.2	36.2	32.9	25.6	18.9

Note. Adapted from "Labor Statistics for Middle-Aged and Older Adults (45+) 2021," by Ministry of Labor, Taiwan, 2021.

From a life-course perspective, Taiwan's market-oriented model generates a fragmented pathway where re-employment opportunities largely depend on individuals' accumulated capital. High-skilled workers can continue with greater flexibility, while low-skilled workers face more precarious exits, potentially reinforcing cumulative disadvantages (Lee & Wang, 2025).

Comparative Analysis

The comparison between Taiwan and Japan reveals that despite contrasting institutional logics—state-directed versus market-oriented—both models reflect a fundamental tension between regulation and limited support. Japan's mandate-driven system achieves high participation rates but may compromise job quality and worker agency. The "salary cliff" and occupational downgrading that accompany continued employment reorganize late-life trajectories in ways that may undermine work dignity (Jiang, 2023).

Taiwan's incentive-based system preserves flexibility but distributes opportunities unevenly, favoring those with greater advantages. This selective activation risks transforming social

investment into a system that rewards those already endowed with human capital while leaving behind those with fragmented careers or limited skills (Ho & Wang, 2024).

Both models, in their current forms, lean toward the "extraction" of existing human capital rather than the "construction" of new capabilities for later life. As Bonoli (2011) notes, active labor market policies often tend to move low-skilled workers quickly into low-paid positions rather than investing in deep skills retraining, challenging the empowering ideals of social investment.

Conclusion

This narrative review has examined Taiwan's and Japan's older adult re-employment policies through the integrated lens of social investment theory and life-course perspective. The analysis reveals that despite divergent institutional logics, both approaches exhibit similar limitations in prioritizing labor force participation over the quality and dignity of late-life work.

A life-course perspective illuminates why current policies may fall short. Late-life employability reflects decades of accumulated advantages and disadvantages shaped by education, occupation, gender, and family responsibilities (Anxo et al., 2010). Policies that focus solely on creating opportunities at the end of the life course, without addressing cumulative deficits, may produce unequal outcomes.

The theoretical implications suggest that social investment policies for older adults must be reconceptualized around the recognition that inadequate investment in early and mid-life stages may amplify disadvantages in later life. For policy development, this analysis suggests moving beyond a binary choice between "mandate" and "incentive" toward frameworks that combine state guarantees with market mechanisms while prioritizing capability building.

Ultimately, enabling dignified late-life work trajectories requires moving beyond narrow labor-utilitarian objectives to embrace a broader vision of social investment—one that treats older adults not as instruments for sustaining economic systems, but as citizens entitled to meaningful and equitable pathways through later life.

Declaration of Generative AI and AI-Assisted Technologies in the Writing Process

The author declares that AI-assisted technologies were used in the preparation of this manuscript. Specifically, the author utilized a large language model (Claude, developed by Anthropic) to assist with language refinement, proofreading, and suggesting improvements to sentence structure and clarity. The AI tool was used under the author's continuous supervision and direction. All intellectual contributions, including the research conceptualization, theoretical framework development, literature collection and analysis, policy comparisons, critical arguments, and final conclusions, are the author's own work. The author takes full responsibility for the originality, accuracy, and integrity of the entire manuscript.

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Community Dance for Active Aging: A Narrative Review on Psychological Well-being of Older Adults

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Abstract

The global trend of population aging underscores the need for effective strategies to promote psychological well-being in older adults. In Taiwan, community dance programs have been widely adopted to foster active aging. This narrative review synthesizes evidence on their impact, utilizing a structured and feasible methodology. Literature was systematically sourced from Taiwanese master's and doctoral thesis repositories, Google Scholar, and the Airiti Library (2000–2025), using keywords including "community dance," "older adults," and "active aging." Studies were included if they involved community-dwelling adults aged 65+ participating in local programs, while reviews and non-Taiwanese studies were excluded. Evidence was categorized according to the active aging framework—health, participation, security—and examined across qualitative, quantitative, and mixed-methods designs. The synthesis indicates that community dance participation is associated with improved mood, reduced loneliness, strengthened social connections, and enhanced cognitive function and self-efficacy. These outcomes align closely with active aging principles. The review concludes that community dance represents a promising, low-cost, and accessible public health intervention. By offering contextualized evidence, it informs policymakers, social workers, and activity coordinators in designing effective community-based programs that support holistic well-being and social integration in later life.

Keywords: community dance, active aging, psychological well-being, older adults, narrative review

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Introduction

The rapid aging of populations worldwide has intensified the search for accessible, community-based interventions that support not only physical health but also psychological well-being in later life. Taiwan became an "aged society" in 2018 and is projected to become a "super-aged society" by 2025 (Ministry of Health and Welfare, Social and Family Affairs Administration, 2022). In response, the government has promoted active aging through policies such as the Active Aging Learning Centers, which provide local, low-threshold opportunities for older adults to engage in lifelong learning and social participation (Li & Wei, 2019).

Among the various programs offered, community dance has emerged as a particularly popular and sustainable form of physical and social activity. Unlike high-intensity sports, dance is adaptable to different functional levels and offers intrinsic motivational elements such as music, rhythm, and social interaction (Chang & Chen, 2014). Research suggests that dance can simultaneously address multiple dimensions of well-being: physical function, emotional regulation, cognitive stimulation, and social connectedness (Lee et al., 2012; Lin & Hua, 2010).

This paper presents a narrative review of the impact of community dance on the psychological well-being of older adults in Taiwan. It is grounded in the World Health Organization's Active Aging Framework (WHO, 2002), which identifies health, participation, and security as three pillars of quality of life in old age. The review aims to synthesize existing evidence, identify key psychosocial outcomes, and discuss implications for policy and practice.

Literature Review

Theoretical Framework: Active Aging

The concept of active aging was formally defined by the World Health Organization (2002) as *"the process of optimizing opportunities for health, participation and security in order to enhance quality of life as people age."* This framework emphasizes that older adults should remain active contributors to society, not only through physical activity but also through social, cultural, and civic engagement (Fernández-Ballesteros et al., 2013).

Fernández-Ballesteros et al. (2013) further elaborated that active aging is an umbrella concept encompassing multiple dimensions: low disease and disability, good physical and cognitive function, positive affect and coping, and active life engagement. Importantly, they note that aging is not genetically predetermined—up to 75% of aging outcomes are influenced by environmental and behavioral factors, positioning older adults as active agents in their own aging process.

Dogra et al. (2022) extended this perspective by introducing a 24-hour behavioral framework, emphasizing the interplay of sleep, sedentary behavior, light physical activity, and moderate-to-vigorous activity. Their review identified five key health outcomes influenced by physical activity: physical function, cognitive function, mental health, social health, and sleep. These domains provide a useful lens for evaluating the multifaceted benefits of community dance.

Community Dance and Psychological Well-being

Empirical studies in Taiwan have consistently demonstrated the psychological benefits of community dance participation. Lin and Hua (2010), in a large-scale survey of 1,728

community college dance participants, found that dance contributed to six types of leisure benefits: social, relaxation, physiological, psychological, aesthetic, and educational. Older participants reported particularly high levels of social benefit, suggesting that dance helps expand social networks that may otherwise shrink with age.

Lee et al. (2012) investigated music and dance activities among 387 older adults in northern Taiwan and found that psychological benefit significantly predicted happiness (path coefficient = 0.48), and in turn, psychological benefit positively influenced physical activity capacity (path coefficient = 0.79). These findings highlight the reciprocal relationship between mental and physical well-being in dance participation.

Caprara et al. (2013), in their evaluation of the Vital Aging Program, demonstrated that multi-component interventions targeting health behaviors, cognition, positive affect, and social participation produced significant improvements in physical activity, dietary habits, memory, emotional balance, and social engagement. Importantly, community-dwelling participants showed greater gains than institutionalized peers, underscoring the role of environmental autonomy.

Social Support and Participation

Social support is a critical mediator of psychological well-being in later life. Chen (2017), in a study of 675 older learners in central Taiwan, found that participants reported high levels of emotional, informational, and instrumental support from their learning environments. Emotional support—feeling cared for and respected—was the most strongly perceived dimension. Chen emphasized that social support buffers stress and enhances life satisfaction, and recommended that programs encourage peer interaction and the formation of self-organized learning groups.

Hsu et al. (2019) examined social determinants of active aging in Taiwan and found significant gender and educational disparities: women were more engaged in volunteerism and social groups, while men had higher employment and physical activity rates. Rural older adults reported better mental health and social integration than their urban counterparts, possibly due to stronger community bonds. These findings suggest that community dance programs must be sensitive to participants' diverse backgrounds.

Physical Function as a Foundation for Psychological Well-being

Physical function is closely linked to psychological outcomes. Lin et al. (2016) found that only 26.5% of older Taiwanese adults met criteria for successful aging, defined as independence in daily activities, normal cognition, absence of depressive symptoms, and good social function. Cardiorespiratory endurance, muscle strength, and balance were significantly associated with successful aging. Regular exercise—at least twice weekly for 20 minutes—was a key protective factor.

Ma et al. (2017) implemented a 12-week fitness program in community care centers and found significant improvements in self-rated health, balance, lower limb strength, and agility. Participants also reported enhanced mood and reduced anxiety. These findings support the use of community-based physical activity programs to promote both physical and mental health.

Aging Attitudes and Mental Health

Attitudes toward aging play a crucial role in psychological well-being. Hsu et al. (2021) found that positive aging attitudes were significantly correlated with better mental health and vitality ($\beta = .39$ and .42, respectively). Older adults who accepted their aging process and maintained a sense of self-worth reported higher psychological well-being. The study recommended that community programs foster positive aging perceptions through engaging, empowering activities such as dance.

Chiu et al. (2024) investigated learning needs for exercise and health programs among middle-aged and older adults. They found that proactive coping behaviors—such as maintaining regular exercise to sustain health—predicted interest in exercise courses. Positive aging attitudes were moderately correlated with proactive coping ($r = .50$), suggesting a virtuous cycle that community dance can reinforce.

Barriers and Motivations

Understanding barriers to participation is essential for program design. Chang and Chen (2014) identified personal, interpersonal, and structural barriers to dance participation among older adults. Personal barriers—such as lack of confidence or perceived inability—were the most significant. Married participants faced more structural barriers due to family responsibilities, while unmarried, widowed, or divorced participants reported higher social benefits from dance, suggesting that dance can serve as a vital source of social connection for those with weaker family ties.

Kuo and Huang (2011) found that motivations for participating in leisure exercise programs included health, social, and achievement needs, all of which were positively correlated with course satisfaction. Participants with lower education levels reported greater psychological gains, highlighting the inclusive potential of community dance.

Community Infrastructure and Policy Support

Lu et al. (2020) developed a group intervention based on the WHO active aging framework and implemented it in two communities in New Taipei City. After 12 weeks, participants showed significant improvements in health, participation, and security behaviors. The study emphasized the importance of group dynamics, role modeling, and individualized support for participants with low literacy or motivation.

Wang and Lee (2016) documented the development of an active aging exercise program in Chiayi City, which included volunteer training, functional fitness assessment, and community-based group exercise. They highlighted the potential of "older adults caring for older adults" as a sustainable model, and recommended intergenerational learning to enhance social cohesion and psychological well-being.

Chen et al. (2025) conducted a prospective study in C-level community care centers and found that health promotion activities—including music-based exercise and group activities—significantly improved muscle mass and maintained bone density. Music-based exercise, in particular, enhanced cognitive function through rhythm repetition and movement memory.

Methodology

This study adopts a narrative review approach, which is appropriate for synthesizing diverse evidence from multiple disciplines and study designs (Green et al., 2006). The methodology follows the steps outlined below:

Search Strategy

Literature was searched from 2000 to 2025 using the following databases:

- Taiwanese master's and doctoral thesis repositories
- Google Scholar
- Airiti Library
- International databases for key theoretical papers (e.g., WHO, Dogra et al., Caprara et al.)

Keywords included combinations of: *community dance, older adults, active aging, psychological well-being, social participation, cognitive function, self-efficacy, Taiwan.*

Inclusion and Exclusion Criteria

Inclusion criteria:

- Studies involving community-dwelling adults aged 65+
- Studies examining community-based dance or movement programs
- Studies reporting psychological or social outcomes
- Taiwanese studies prioritized for contextual relevance

Exclusion criteria:

- Review articles (used only for background)
- Studies conducted in institutional settings
- Non-Taiwanese studies (except for theoretical frameworks)

Data Extraction and Synthesis

Extracted data included: author(s), year, setting, sample characteristics, intervention type, outcomes measured, and key findings. Evidence was categorized according to the WHO active aging framework (health, participation, security) and further organized by study design (qualitative, quantitative, mixed-methods).

Results

Study Selection

A total of 21 studies were included in this review: 4 theoretical papers, 7 quantitative studies, 4 qualitative studies, and 6 mixed-methods studies. All empirical studies were conducted in Taiwan between 2009 and 2025.

Psychological Outcomes of Community Dance

Emotional Well-being

Multiple studies reported improvements in mood, stress reduction, and emotional balance. Lee et al. (2012) found that music and dance participation significantly predicted happiness through psychological benefit. Lin and Hua (2010) reported that participants agreed dance helped them "forget worries" and "recover energy." Caprara et al. (2013) documented increases in positive affect and decreases in negative affect following the Vital Aging Program.

Social Connectedness

Social benefits were consistently reported across studies. Lin and Hua (2010) found that older participants valued the social dimension of dance most highly. Chang & Chen (2014) noted that unmarried, widowed, or divorced participants experienced greater social benefits from dance, suggesting it compensates for lack of family support. Chen (2017) emphasized that learning environments provide emotional support, which is critical for mental health.

Cognitive Function

Several studies pointed to cognitive benefits. Lin et al. (2016) linked physical fitness to cognitive function in successful aging. Chen et al. (2025) highlighted that music-based exercise enhances memory through rhythm and repetition. Caprara et al. (2013) found that participants in the Vital Aging Program reported improved self-rated memory and more frequent use of memory strategies.

Self-Efficacy and Personal Growth

Dance participation fosters a sense of achievement and self-worth. Yu (2013) documented that community dancers experienced "psychological satisfaction" and "a sense of accomplishment that money cannot replace." Chang and Chen (2014) identified "learning and self-actualization" as a distinct benefit dimension. Participants with lower education levels reported greater psychological gains, underscoring the inclusive nature of dance.

Alignment With Active Aging Framework

The reviewed evidence aligns well with the three pillars of active aging:

- Health: Improved physical function, reduced stress, better sleep (Chen et al., 2025; Lee et al., 2012; Ma et al., 2017)
- Participation: Increased social interaction, group cohesion, community engagement (Chen, 2017; Lin & Hua, 2010; Lu et al., 2020)
- Security: Enhanced self-efficacy, emotional support, reduced loneliness (Chang & Chen, 2014; Hsu et al., 2021)

Discussion

This narrative review confirms that community dance is a viable, low-cost, and culturally appropriate intervention for promoting psychological well-being among older adults in Taiwan. The findings resonate with international frameworks (Dogra et al., 2022; Fernández-Ballesteros et al., 2013; WHO, 2002) and are strongly supported by local empirical research.

Theoretical Implications

The study reinforces the multidimensional nature of active aging. Dance is not merely physical exercise; it is a vehicle for emotional expression, cognitive stimulation, and social bonding. As Fernández-Ballesteros et al. (2013) argued, aging is shaped by environment and behavior—community dance offers an enriched environment that activates multiple psychological resources.

The findings also support the 24-hour behavior framework proposed by Dogra et al. (2022). Dance reduces sedentary time, promotes light-to-moderate activity, and enhances sleep quality—all of which contribute to mental health.

Practical Implications

For practitioners, the following recommendations emerge:

- Design for inclusivity: Programs should accommodate varying functional levels, educational backgrounds, and family situations.
- Foster social support: Create opportunities for peer interaction, group cohesion, and emotional bonding.
- Integrate cognitive elements: Use music, rhythm, and choreography to stimulate memory and learning.
- Empower participants: Encourage self-organized groups and peer leadership to sustain engagement.
- Leverage community infrastructure: Utilize Active Aging Learning Centers, community care stations, and local volunteers to enhance accessibility.

Policy Implications

At the policy level, the findings support continued investment in community-based active aging programs. Hsu et al. (2019) highlighted disparities in active aging opportunities by gender, education, and urban-rural residence. Community dance programs can help bridge these gaps if designed with equity in mind. Policies should also support training for older adult volunteers to lead programs, fostering a sustainable "older caring for older" model (Wang & Lee, 2016).

Limitations

This review has several limitations. As a narrative review, it does not quantify effect sizes or test for publication bias. Most included studies are cross-sectional or quasi-experimental, limiting causal inference. The focus on Taiwan, while contextually valuable, may limit generalizability to other cultural settings.

Future Research

Future studies should:

- Employ longitudinal or experimental designs to establish causality
- Use standardized measures of psychological well-being
- Examine dose-response relationships (frequency, duration, intensity)
- Explore mechanisms linking dance to psychological outcomes
- Compare different dance forms and instructional approaches

- Investigate the role of digital tools in sustaining engagement

Conclusion

Community dance is a powerful, culturally resonant intervention that promotes psychological well-being in older adults. Grounded in the WHO Active Aging Framework and supported by a growing body of Taiwanese research, dance programs enhance emotional health, social connectedness, cognitive function, and self-efficacy. By integrating health, participation, and security, community dance contributes to holistic aging and quality of life. Policymakers, community organizers, and health professionals should prioritize and support such programs as part of a comprehensive strategy for active aging.

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Declaration of Generative AI and AI-Assisted Technologies in the Writing Process

The authors declare that ChatGPT (OpenAI) was used to assist in drafting and refining the language of this manuscript, based on the authors' original research and literature synthesis. All ideas, interpretations, and conclusions are the authors' own. The authors take full responsibility for the content of this paper.

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Reflections on the Use of Collaborative Action Research to Improve the *Come! Let's Chat* Game

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Abstract

Come! Let's Chat (CLC) game was designed for conducting reminiscence activity with older adults. Certified *CLC* facilitators administer a set of pictures of local scenarios, many of which depict the past, to evoke older adults' memories and engage in meaningful conversations. Launched recently in Singapore, and now used in Hong Kong and Taiwan, *CLC* will soon be introduced in China, Indonesia, and India. It is timely then, to examine usable research protocols to improve the *CLC* by building on its strengths and addressing its weaknesses. This paper presents one such effort. In 2025, collaborative action research was conducted on the original Singapore version of *CLC.* Six certified *CLC* facilitators served as co-researchers across two iterative action-research cycles. In Cycle 1, they conducted sessions with the original game, and data from interviews and document review informed several refinements which were then piloted and evaluated in Cycle 2. Thematic analysis culminated in recommendations for the revision of *CLC* version 1. Grounded in this research, we share insights about the scope for periodic collaborative action research to be an integrated part of programmes such as the *CLC*. The *CLC's* multi-agency collaboration—including trained facilitators at active-ageing centres, gerontologists in academia, and the corporate funder—is a common feature of similar programmes for older adults. Hence, we examine the potential transferability of our takeaways from this research project to other programmes for healthy ageing.

Keywords: reminiscence facilitation, collaborative action research, reminiscence-based tool, intergenerational relationships, older adults

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Introduction

Singapore is among the most rapidly ageing countries globally. According to the United Nations, a nation is classified as "ageing" when at least 7% of its population is aged 65 and above, "aged" at 14%, and "super-aged" at 21%. Singapore has reached "aged" status and is transitioning into "super aged" in 2026. By 2030, it is projected that one in four citizens will be aged 65 and above (Ministry of Health, n.d.).

Against this backdrop, the *Come! Let's Chat (CLC)* game was developed in Singapore as a structured reminiscence intervention using visual prompts grounded in local and historical contexts. Alongside with the game, a Reminiscence Facilitation Training (RFT) programme was introduced to equip facilitators with skills required to guide reminiscence sessions effectively. Since its launch in 2023, the programme has grown significantly, with over 200 facilitators trained in Singapore and additional facilitators in Taiwan and Hong Kong. Plans are underway to introduce the programme elsewhere in China, as well as in Indonesia and India.

Despite its promising reach, there were questions such as whether the game was inclusive enough given the cultural diversity in Singapore. There had been no published research examining its implementation in practice. Most importantly, facilitators' insights remained underexplored, even though they played a key role in delivering the intervention. Without a deeper understanding of their experiences and challenges, the game may not fully realise its potential to foster meaningful intergenerational reminiscence.

This study therefore sought to improve the design and delivery of the *CLC* game, generate evidence-based recommendations for facilitation and training, and contribute to the limited body of research on intergenerational, game-based reminiscence interventions. The research is guided by five key questions focusing on the enhancement of the game's design, the improvement of the pre-session preparation, the competencies required for effective facilitation, the identification of suitable participant profiles, and the improvement of post-session evaluation processes.

Methodology

This study adopted a collaborative action research (CAR) approach, a participatory methodology that emphasises iterative cycles of planning, action, observation and reflection to address real-world challenges (Adelman, 1993). CAR was particularly appropriate for this study as it focused on practice-based improvement and allowed for the active involvement of reminiscence facilitators in the research process. By positioning facilitators as co-researchers, the study ensured that the insights generated were grounded in real implementation contexts rather than conceptual evaluation (Bleicher, 2014; Mitchell et. al., 2009).

Participants were recruited through criterion-based purposive sampling. The study involved six certified reminiscence facilitators who had completed the SUSS Reminiscence Facilitation training programme, and had conducted at least ten reminiscence sessions within the preceding twelve months. These facilitators were selected not only for their experience but also for their ability to participate fully in both cycles of the research and contribute to reflective discussions. Their role as co-researchers enabled a collaborative and iterative process of programme improvements.

The research involved two cycles of CAR, each comprising the phases of planning, acting, observing, and reflecting. Cycle 1, the lead researcher (Eunice Frances Chan) and the participant co-researchers (the *CLC* facilitators) jointly established research goals, defined session objectives and planned facilitation strategies. The participating *CLC f*acilitators then conducted reminiscence sessions using the original version of the *CLC* game. During this phrase, data were collected through interviews, artefacts, documents and facilitators reflections, capturing insights into client engagement, interactions and implementation challenges (Arefian, 2022; Arefian & Nami, 2023; Atay, 2008; Cabaroglu, 2014; O'Leary, 2004; Qing-li et al., 2018; Vescio et al., 2008).

Following Cycle 1, the *CLC* facilitators and the lead researcher engaged in collective reflection to identify both strengths and areas for improvement. These reflections informed a series of modifications to the game, including the introduction of six new box design proposals, thirty-one additional visual cards, and five new open-ended questions designed to broaden discussion themes.

In the second cycle, *CLC* facilitators implemented the revised version of the game in a new round of reminiscence sessions, with at least four weeks to trial these revised materials. Data collection and reflection processes were repeated, enabling the research team to assess the effectiveness of the modifications and identify further areas for refinement. This iterative process allowed the game to evolve through continuous feedback and collaborative learning.

Data from both cycles were analysed using thematic analysis, to identify recurring patterns related to design, facilitation, and participant engagement. Themes were refined across cycles to ensure that they reflected the complexities of real-world practice.

Researcher Insights

This study prompted several insights about the *CLC* game design and the processes, as well as the value of conducting action research using the CAR approach. In this section, we share in first person several key thoughts as captured in the journal of the lead researcher, Chan.

Situated within Singapore's multi-racial context—comprising Chinese, Malay, Indian and Other communities, with major religions including Buddhism, Christianity, Islam, Taoism and Hinduism—one of the most significant reflections concerns inclusivity in the programme design (Singapore Department of Statistics, 2020).

Through the sessions, I became increasingly aware that participants engaged with visual prompts in different ways, often shaped by their cultural backgrounds and personal experiences. What I had initially assumed to be broadly relatable content did not resonate equally with all participants. This prompted me to reconsider the idea of a universally applicable intervention and recognise that inclusivity cannot be assumed—it must be intentionally and thoughtfully embedded. This reflection has highlighted the importance of designing with, rather than for, diverse groups, ensuring that representation is meaningful and contextually relevant.

Another key reflection relates to the role of facilitation. I came to understand that the success of the game was not solely dependent on its design, but significantly influenced by how it was facilitated. Observing and engaging in sessions made me more aware of the importance of creating a psychologically safe environment, especially when participants shared personal or emotionally charged memories. Some prompts, particularly those connected with historical

events, evoked strong emotional responses, and I realized the need for facilitators to be equipped with sensitivity and appropriate skills to navigate such moments. This experience reshaped my perception of the game—from being a structured activity to a relational experience shaped by the interactions between participants, facilitators, and materials.

I also reflected on the complexity of the co-creation process within CAR. Rather than following a straightforward or liner path, the process was dynamic and at times challenging, requiring continuous reflection, negotiation, and adaption. This challenged my initial expectations and pushed me to become more open to uncertainty and change. Over time, my role shifted from that of a developer focused on outcomes to a listener and facilitator of collective learning. This shift deepened my awareness of issues such as identity, representation, and inclusivity, and emphasized the importance of remaining responsive to feedback throughout the process.

Finally, the iterative nature of the research process allowed me to reflect on the value of ongoing refinement. Observing improvements in later cycles—such as greater participant engagement, smoother conversations, and increased facilitator confidence—reinforced my understanding that meaningful practice develops over time through reflection and adaptation. These experiences have strengthened my appreciation of CAR as a reflective, evolving approach to developing practice-based interventions.

Concluding Thoughts

The findings of this study highlight the importance of viewing reminiscence interventions as dynamic and context-dependent rather than static tools. The effectiveness of such interventions depends not only on their design, but also on the relational and environmental contexts in which they are carried out.

The study underscores the need for intentional inclusivity in programme design, particularly in multicultural settings. It also reinforces the central role of facilitators in shaping participant experiences and outcomes. By foregrounding practitioner insights, the study contributes to a more grounded understanding of intervention success.

CAR proved to be a valuable methodological approach, enabling real-time improvement and fostering a sense of shared ownership of the study with the participant co-researchers. It provided a framework for integrating reflection and practice, bridging the gap between theory and practice.

Looking Forward

This study is limited by its small sample size. In addition, this action research did not directly capture the experiences of the older adult clients who played the game. We hope future research will be done with greater participation of programme stakeholder, including clients as co-researchers.

While this action research met its purpose of improving *CLC* programme, future studies could investigate *CLC* participant outcomes for both older adults and younger game facilitators in intergenerational settings. Also, as the *CLC* programme is implemented in other Asian countries. There is also a need to explore its adaptation across different cultural contexts. As such, we see the *CLC* game as a continuously evolving tool, supported by ongoing feedback and collaboration.

This study demonstrates the CAR provides a structured yet adaptable framework for improving community-based interventions. The findings highlight the importance of inclusivity, facilitation, and continuous adaptation in the design and delivery of reminiscence-based programmes.

Ultimately, the study underscores that meaningful interventions are not static products but evolving practices shaped through listening, reflection and collaboration. As ageing populations continue to grow, such approaches will be essential in developing responsive and sustainable programmes that support the well-being of older adults.

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Declaration of Generative AI and AI-Assisted Technologies in the Writing Process

During the preparation of this work, ChatGPT was used to refine sentence structure, improve clarity and tone, and suggest alternative vocabulary, and the Scribbr Citation Generation for APA 7 alignment for citations and references. The authors reviewed and edited all content and takes full responsibility for the final work.

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The Cumulative Effect of Number of Children on Wage Disparities by Gender in Later Life

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Abstract

This study examines whether the effects of childbearing on women's wages persist and accumulate into later life, contributing to gendered wage disparities among older workers. Drawing on a life course perspective and gendered cumulative disadvantage theory, the study analyzes KLoSA panel data (2006–2022) for individuals aged 65 to 85 using three analytical models: Random Effects, Fixed Effects, and Growth Curve Models. Results show that older women consistently earn less than older men, and that the gender wage gap has widened over time. More children are associated with lower wages for both genders; however, wage trajectory analysis reveals that the number of children significantly slows wage growth only among older women, not among men. Women with two or more children exhibit markedly slower wage growth over time, while those with three or more children show virtually no wage growth throughout the observation period. These findings demonstrate that childbearing constraints accumulate across the life course and continue to shape economic outcomes in later life, operating as a structural mechanism of gendered inequality.

Keywords: aging, gender wage gap, life course, cumulative disadvantage, child penalty

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Introduction

South Korea entered a super-aged society in 2024, and the employment rate of older adults is among the highest in the OECD. However, many older adults work out of economic necessity rather than choice, and poverty rates among the elderly remain exceptionally high. These conditions reflect not simply the absence of adequate welfare provisions, but the cumulative outcome of a lifetime of unequal labor market experiences.

Among the structural factors shaping economic inequality in later life, gender is particularly consequential. Older women exhibit higher poverty rates than men, and the gender wage gap becomes more pronounced with age. This study focuses on one key mechanism underlying this pattern: the number of children. While prior research has established that childbearing constrains women's labor force participation and wages during working-age years, far less is known about whether these effects persist into later life and continue to shape how wages evolve over time.

This study addresses that gap by asking: does the number of children affect wage trajectories in later life, and do these effects differ by gender? Using KLoSA panel data from 2006 to 2022 and a three-model analytical strategy, this paper examines wage levels, within-person wage changes, and long-term wage growth trajectories among older Korean workers aged 65 to 85. The findings contribute to our understanding of how early-life caregiving responsibilities translate into lasting economic disadvantage.

Literature Review

Although older adults are frequently analyzed as a single age-based category, the elderly population is fundamentally heterogeneous in character. Even within the same age cohort, individuals do not share equivalent experiences or social positions, as each person occupies a distinct location shaped by a divergent life course (Laslett, 1996; Son, 2009). This internal heterogeneity is particularly consequential for understanding labor market participation in later life. Given that old age is the cumulative product of an entire life course, the labor conditions and income levels of older workers must be understood not as age effects but as the structured outcomes of accumulated experience (Son, 2009).

Research on the life course perspective has consistently demonstrated that inequality is not a snapshot at any given moment but the product of accumulated advantages and disadvantages over time (Mayer, 2009). Cumulative disadvantage theory further elaborates that early-life inequalities compound with age, producing increasingly divergent outcomes across individuals (DiPrete & Eirich, 2006). Prior studies on Korean elderly populations corroborate this perspective, showing that current income inequality reflects differences in life trajectories, and that labor market advantages and vulnerabilities in younger years exert a lasting influence into old age (Hwang & Kim, 2013; Son, 2009). Concretely, those who held stable, well-paying employment during their prime working years tend to maintain stable labor and income after retirement, while those who did not are more likely to remain in precarious and low-income conditions in old age (Seok & Im, 2007; Son, 2009).

These accumulated inequalities are, however, not gender-neutral in how they form. Because the life stage characterized by productive labor and career investment structurally overlaps with the period of childbearing and caregiving, women are confronted with a double burden that is difficult to sustain simultaneously (Moen, 1992, 2011). Applied to gender, the cumulative

disadvantage framework highlights that women's dual responsibilities in paid and unpaid work generate career interruptions with long-term consequences for wages, employment stability, and advancement opportunities (DiPrete & Eirich, 2006). Women who exit or transition out of the labor market due to caregiving responsibilities experience reduced tenure, wage loss, diminished job security, and constrained promotion prospects (Kim, 2017; Moen, 1992).

Within this broader structure, the number of children functions as a concrete and quantifiable indicator of caregiving burden and its associated labor market pressures. Research has shown that between the 1940s and 1960s, the number of children and age were the most accurate predictors of women's employment in the United States (Moen, 1992). Women with more children were more likely to exit the labor force, accept part-time or lower-paying positions offering scheduling flexibility, or delay childbirth and reduce family size in order to maintain labor force attachment (Budig & England, 2001; Moen, 1992). These interruptions disrupt human capital accumulation and seniority-based wage progression common in many labor markets. For men, by contrast, childbearing has frequently been associated with a wage premium, as fatherhood is linked to perceptions of reliability and commitment (Correll et al., 2007). This asymmetry underscores the extent to which the effects of children on labor market outcomes are structured by gender.

Studies that have extended the analysis to older populations confirm that such effects persist into later life. Among Korean elderly women, those with a greater number of children are more likely to enter low-wage, unstable occupations in old age (Lee, 2023), and the accumulation of children has been shown to exert a negative effect on income levels in later life (Jang & Choi, 2025). Research examining school-age and preschool-age children separately has further shown that the presence of preschool children may constitute a particular constraint on women's re-entry into employment (Park et al., 2022).

Nevertheless, existing research is subject to several important limitations. First, studies analyzing the effect of children on elderly women's income often restrict their samples to women alone, making gender comparison structurally impossible and weakening the evidential basis for gender-based arguments (Jang & Choi, 2025). Second, by treating women as a homogeneous group, this body of research forecloses examination of within-group heterogeneity — that is, the extent to which women's outcomes in later life diverge depending on their individual family and labor histories. Third, prior research has largely treated the number of children as a determinant of static outcomes such as occupational status or income level at a given point, without examining whether and how it shapes wage trajectories over time. The question of whether the number of children influences not only where older women are positioned in the labor market but how their wages change across time remains insufficiently addressed. The present study directly addresses this gap by incorporating both men and women into a comparative framework and examining wage change trajectories among elderly workers in South Korea.

Based on the theoretical framework and prior literature, the following hypotheses are proposed:

Hypothesis 1 (H1). Older women are expected to exhibit lower average wages than older men.

Hypothesis 2 (H2). A greater number of children is expected to be negatively associated with average wages among older workers.

Hypothesis 3 (H3). The effect of number of children on wage growth trajectories is expected to be significant among older women only.

Methodology

Data

This study uses data from the Korean Longitudinal Study of Ageing (KLoSA). KLoSA surveys individuals aged 45 and older residing across the country (excluding Jeju Island), with biennial main surveys conducted in even-numbered years. The data used in this analysis are restructured files that include variables derived and organized from the original raw data. As the dataset is designed specifically for older populations, it was deemed appropriate for research on an aged society.

The analytic scope covers Waves 1 through 9 (2006–2022), and panel data were used accordingly. While cross-sectional data can capture wage gaps at a single point in time, they are limited in their ability to track whether such gaps widen or narrow over time. Panel data were therefore selected to enable longitudinal analysis.

Individual-level, rather than household-level, data were used in order to examine gender-based wage gaps and life course differences. Individual-level data are better suited to capturing personal experiences and thus allow for greater analytical precision.

Analytic Sample

It has been noted that defining "older adults" is challenging due to the flexibility inherent in biological and social criteria (Laslett, 1996). Existing studies vary in the age thresholds they apply depending on their research objectives. This study focuses on the labor of older adults and accordingly sets the lower age boundary at 65, as this is the age threshold used in most social security systems and is generally considered the point at which post-retirement employment becomes active (Kim, 2021). The upper age limit was set at 85 in order to restrict the sample to individuals who are realistically engaged in paid work. To account for the nonlinearity of age effects, both a linear age term and a squared age term were included in the analytic models.

Cases with missing responses on "total wage income in the previous year" were treated as missing, and a log transformation was applied to reduce skewness. A one-period lag was applied given that the survey item refers to the previous year.

Number of children was categorized into three groups: "0–1 child," "2 children," and "3 or more children." The 0- and 1-child categories were combined due to their small proportions (2.36% and 9.23%, respectively), and because from a life course perspective, having two or more children involves distinct patterns of childbearing, caregiving, and career interruption that justify treating them as separate categories.

Marital status was coded as "married" or "not married" (including separated, divorced, widowed, and never married). Education was categorized into four groups: elementary school or below, middle school graduate, high school graduate, and college graduate or above. Self-rated health was measured on a five-point scale. The residential area variable was recoded into a binary distinguishing "urban" (metropolitan city) from "non-urban" (small-to-medium city and rural area). Asset income was coded as "has asset income" if any asset income was reported, and "no asset income" otherwise.

Analytic Strategy

The analysis draws on KLoSA panel data and proceeds in several steps: descriptive statistics, examination of wage income distributions and wage trends, followed by panel random effects models and growth curve models (GCM). Descriptive statistics provide a foundational overview of the sample's characteristics, upon which the subsequent models are built. Given the panel structure of the data, descriptive statistics are presented for the full panel sample and serve as contextual background for interpreting the analyses. Distributions of wage income and wage trends are also included, as they serve as indicators of how income gaps manifest in later life according to gender.

The panel random effects model is based on the assumption that unobserved individual heterogeneity is uncorrelated with all observed explanatory variables (Allison, 2009). This model is used to examine the association between number of children and wages in later life. However, the random effects model has limitations in capturing change over time, and the growth curve model is therefore employed to complement the analysis of wage trajectories. The growth curve model treats between-individual differences as random effects, allowing for the simultaneous estimation of heterogeneity in both initial wage levels and rates of change over time (Allison, 2009). It also has the advantage of constructing long-term trajectories from partially observed cohorts, thereby addressing issues of missing data and irregular observation intervals common in longitudinal data (Raudenbush & Chan, 1992). Together, these two models allow for a more comprehensive understanding of wage inequality in later life by capturing both the level and the trajectory of wage gaps.

Findings

Descriptive Statistics

Table 1 presents descriptive statistics for the full panel sample, comprising 8,547 observations from approximately 3,000 unique individuals. The mean age is 71.38 years, consistent with the study's focus on adults aged 65 to 85, and the mean log-transformed wage income is 6.70. Women account for 34.81% of the sample, and 79.85% of respondents are currently married. The mean number of children is 2.60. The mean education level of 1.82 falls between the “elementary school or below” and “middle school graduate” categories, and mean self-rated health is 2.99 on a five-point scale. The proportion reporting asset income is 16.56%, and 30.07% reside in urban areas.

Table 1
Descriptive Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
Year	8,547	2014.187	5.079729	2006	2022
Female	8,547	0.3480753	0.4763879	0	1
Wage income (log)	8,547	6.702816	1.037881	0	11.0021
Number of Children	8,547	2.602083	0.598743	1	3
Age	8,547	71.37908	4.962152	65	85
Age2	8,547	5119.593	725.4624	4225	7225

Education	8,547	1.823096	1.002368	1	4
Self-rated health	8,547	2.986545	0.799562	1	5
Marital status	8,547	0.7985258	0.4011249	0	1
Urban residence	8,547	0.3006903	0.4585851	0	1
Asset ownership	8,547	0.1655552	0.3717026	0	1

Note. N = 8,547 person-wave observations from approximately 3,000 unique individuals.

Descriptive Patterns

Figure 1 presents gender-specific mean wage trends among older adults from 2006 to 2022. Across the entire observation period, mean wages for older male workers are consistently higher than those for older female workers. While mean wages for both men and women show an overall upward trend since 2006, the rate of wage growth for women is comparatively slower than that for men, indicating that the gender wage gap has persisted throughout the period.

These findings suggest that the wage gap between older male and female workers is a longstanding phenomenon that continues to the present. Notably, despite a general increase in average wage levels over time, the gap itself has not narrowed. While the gender wage gap is clearly observable, however, interpreting it solely as the effect of gender is insufficient. Given that men and women follow distinct life course trajectories and accumulate different experiences over time, further analysis is warranted to better understand the mechanisms underlying this gap.

Figure 1
Gender Wage Trends, 2006–2022

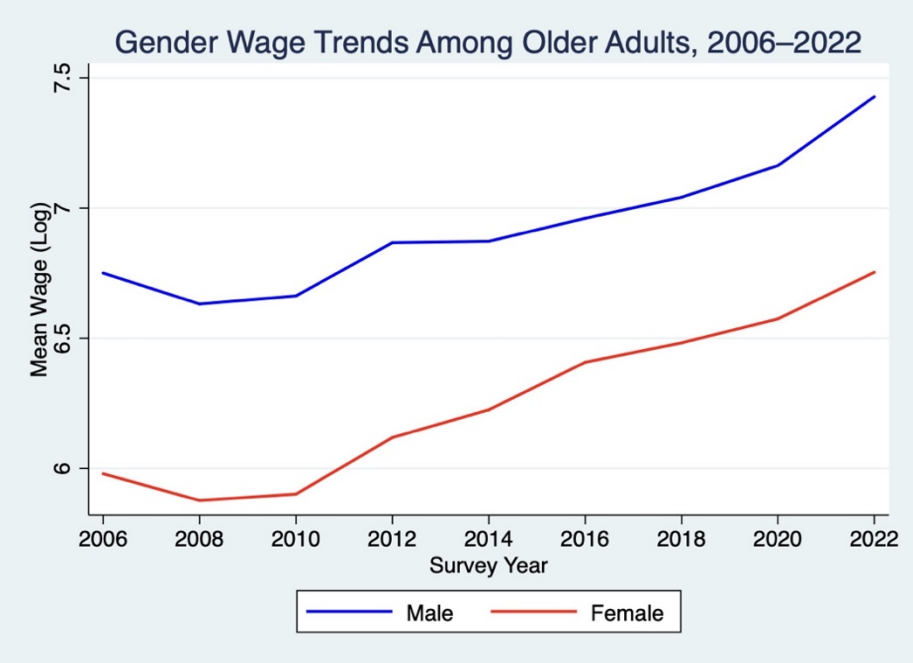


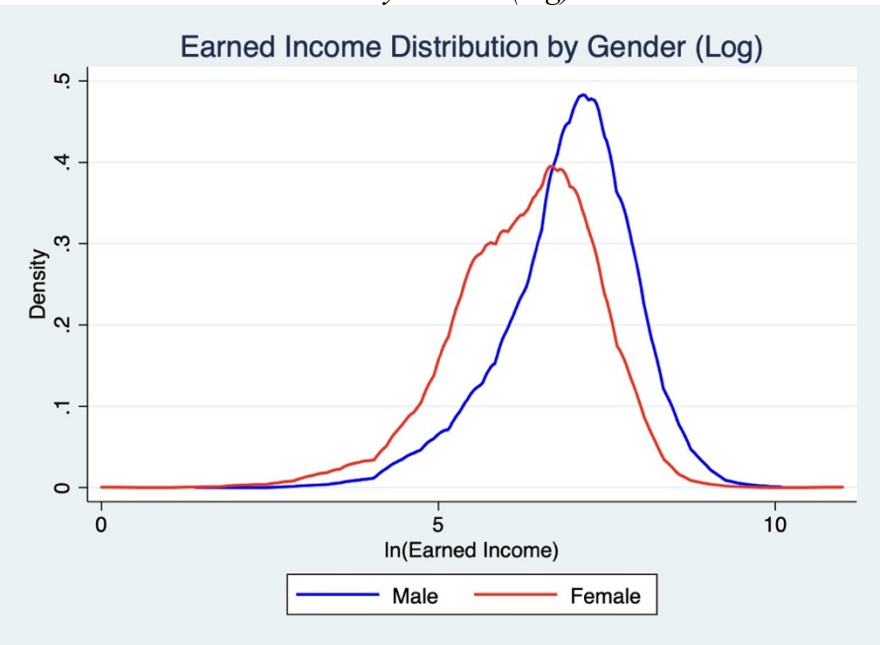
Figure 2 compares the earned income distributions of older male and female workers, demonstrating that the gender wage gap is present across the entire wage distribution. While the two distributions share certain similarities, clear differences in their shape are evident.

Older male workers are observed to be more heavily concentrated in higher wage ranges, whereas older female workers are more densely distributed in lower wage ranges. Moreover, even within the same wage range, women account for a smaller share than men. This indicates that men tend to cluster more strongly at higher income levels. These distributional differences confirm that the gender wage gap exists across the full spectrum of the income distribution.

Taken together, the preceding analyses demonstrate that the gender wage gap among older adults has persisted over an extended period and is distributed across the entire income range. These findings provide a foundation for understanding the nature and structure of wage inequality in later life. Building on these results, panel random effects models and growth curve models are employed to examine the effect of number of children on wages by gender, as well as to identify gender-specific wage trajectories.

Figure 2

Earned Income Distribution by Gender (log)



Random Effects Model (RE)

Using a panel random effects model, this study examined how the number of children and other individual-level variables are associated with wage levels among older adults, separately by gender. The number of children was found to be significantly associated with earned income for both men and women, with a greater number of children corresponding to lower earnings. The effect of the children variable on earned income thus showed no substantial difference between the two gender groups.

Age was not statistically significant in either group, indicating no clear relationship between age and earned income. Educational attainment was significantly associated with earned income in both groups. Marital status, self-rated health, and asset ownership all showed significant positive associations with earned income for both older men and women.

These findings suggest that individual characteristics may be associated with wages in later life. Notably, the significant association between number of children and earned income for both men and women implies that caregiving responsibilities may negatively affect income

regardless of gender. Given that the random effects model accounts for both between-individual differences and within-individual variation over time, it is capable of capturing the association between number of children and wages; however, it is limited in its ability to explain the wage trajectories of men and women over time. The central question regarding the gender wage gap in old age concerns whether the gap emerges anew in later life, what trajectory it follows over time, and how it varies by gender and number of children. Old age is not a period in which new inequalities arise, but rather one in which previously accumulated inequalities manifest in a concentrated form. The wage trajectories of older adults are therefore not simply the product of an age effect, but are the cumulative outcome of labor market experiences across the life course—and as such, constitute an important object of analysis for verifying this process.

Table 2

RE

VARIABLES	Male	Female
Number of children	-0.152*** (0.031)	-0.120*** (0.046)
Age	0.031 (0.060)	0.070 (0.112)
Age2	-0.00038 (0.0004)	-0.001 (0.001)
Middle (ref. Elementary)	0.296*** (0.052)	0.468*** (0.074)
High school	0.431*** (0.047)	0.677*** (0.084)
College or higher	0.581*** (0.076)	0.558*** (0.211)
Marital	0.125* (0.066)	0.100** (0.048)
Self-rated health	0.073*** (0.015)	0.090*** (0.024)
Asset ownership	0.067** (0.028)	0.120** (0.048)
Constant	6.475*** (2.174)	4.385 (4.052)
Observations	5,572	2,975
Number of pid	1,826	1,205

Note. Standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Fixed Effects Model (FE)

To address potential bias arising from unobserved time-invariant individual characteristics, a fixed effects (FE) model was estimated separately for older men and women. As shown in Table 4, neither the time slope nor any of the children × time interaction terms reached statistical significance for either gender group. For older men, the time coefficient was negative and non-significant ($\beta = -0.021$), and the interaction terms for two children ($\beta = 0.013$) and three or more children ($\beta = 0.004$) were likewise insignificant. A parallel pattern was observed among older women, with a near-zero time slope ($\beta = 0.002$) and non-significant interaction effects for both child-count categories. These results indicate that once unobserved individual heterogeneity is accounted for, the effect of number of children on within-person wage change is no longer detectable for either men or women.

This null finding is theoretically interpretable rather than simply a failure of detection. Because number of children is a time-invariant characteristic, its influence is fully absorbed into the individual fixed effects and cannot be separately identified within the FE framework. The FE model is therefore structurally limited in its capacity to capture how a stable life-course variable such as fertility history shapes long-run wage trajectories. This limitation motivates the use of a Growth Curve Model (GCM) as the primary analytical strategy, as GCM is better suited to modeling the ways in which time-invariant characteristics — including number of children — differentially condition the rate and direction of wage change over time.

Table 3
FE

VARIABLES	Male	Female
t (time)	-0.0211 (0.0168)	0.00207 (0.0218)
(ref. Children 0–1) 2 children	-0.106 (0.266)	0.265 (0.366)
3 + children	-0.0537 (0.294)	-0.0845 (0.421)
2 Children * t	0.0130 (0.0179)	-0.0218 (0.0270)
3+ Children * t	0.00374 (0.0173)	-0.00660 (0.0227)
(ref. Elementary) Middle school	-0.144 (0.394)	0.569*** (0.0300)
High school	-0.134 (0.273)	-0.602** (0.302)
College or higher	-0.573 (0.413)	(omitted)
Marital	0.107 (0.101)	-0.0159 (0.0750)
Self-rated health	0.0339** (0.0167)	0.0281 (0.0288)
Asset ownership	-0.0101 (0.0308)	-0.0294 (0.0571)
Constant	7.027*** (0.331)	6.271*** (0.368)
Observations	5,572	2,975
Number of groups	1,826	1,205

Note. Standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Growth Curve Model (GCM)

The Growth Curve Model (GCM) was estimated to examine how the number of children shapes wage trajectories over time among older workers, allowing for the differential conditioning of wage growth by this time-invariant life-course variable. The results first establish that wage trajectories in later life are not static: the time slope was positive and statistically significant for both older men ($\beta = 0.022$, $p < 0.1$) and older women ($\beta = 0.063$, $p < 0.01$), indicating that wages continue to increase over time for both gender groups, with women exhibiting a steeper average rate of growth.

The critical finding, however, lies in the children × time interaction terms, which reveal a pronounced gender asymmetry. Among older men, neither the two-children ($\beta = -0.003$, n.s.) nor the three-or-more-children interaction term ($\beta = -0.019$, n.s.) reached statistical significance, indicating that the number of children does not significantly differentiate wage trajectories among older male workers. Among older women, by contrast, both interaction terms were negative and statistically significant: women with two children experienced a significantly slower rate of wage growth over time ($\beta = -0.042$, $p < 0.05$), as did women with three or more children ($\beta = -0.039$, $p < 0.05$), relative to those with zero or one child. These results provide support for Hypothesis 3, confirming that the constraining effect of number of children on wage trajectories operates exclusively among older women. This gendered pattern is consistent with a cumulative disadvantage framework, wherein caregiving responsibilities — disproportionately borne by women across the life course — continue to exert a suppressive effect on wage growth well into later life, producing a progressively widening divergence in earnings trajectories between older women with differing reproductive histories.

Table 4
GCM

VARIABLES	Male	Female
t (time)	0.0220* (0.0116)	0.063*** (0.017)
(ref. children 0–1) 2 children	0.058 (0.149)	0.581** (0.242)
3+ children	-0.0585 (0.141)	0.339 (0.214)
2 Children * t	-0.00346 (0.0126)	-0.042** (0.019)
3+ Children * t	-0.0188 (0.0122)	-0.039** (0.017)
(ref. Elementary) Middle school	0.312*** (0.0538)	0.378*** (0.077)
High school	0.460*** (0.0474)	0.588*** (0.087)
College or higher	0.588*** (0.0672)	0.449** (0.175)
Marital	0.161*** (0.0616)	0.228*** (0.046)
(ref. very poor) Self-rated health Poor	0.244*** (0.0630)	0.295*** (0.076)
Fair	0.365*** (0.0627)	0.352*** (0.078)
Good	0.413*** (0.0643)	0.413*** (0.086)
Very Good	0.524*** (0.0978)	0.735*** (0.188)
Asset ownership	0.0358 (0.0266)	0.132*** (0.048)
Constant	6.066*** (0.158)	5.063*** (0.220)
Observations	5,572	2,975
Number of groups	1,826	1,205

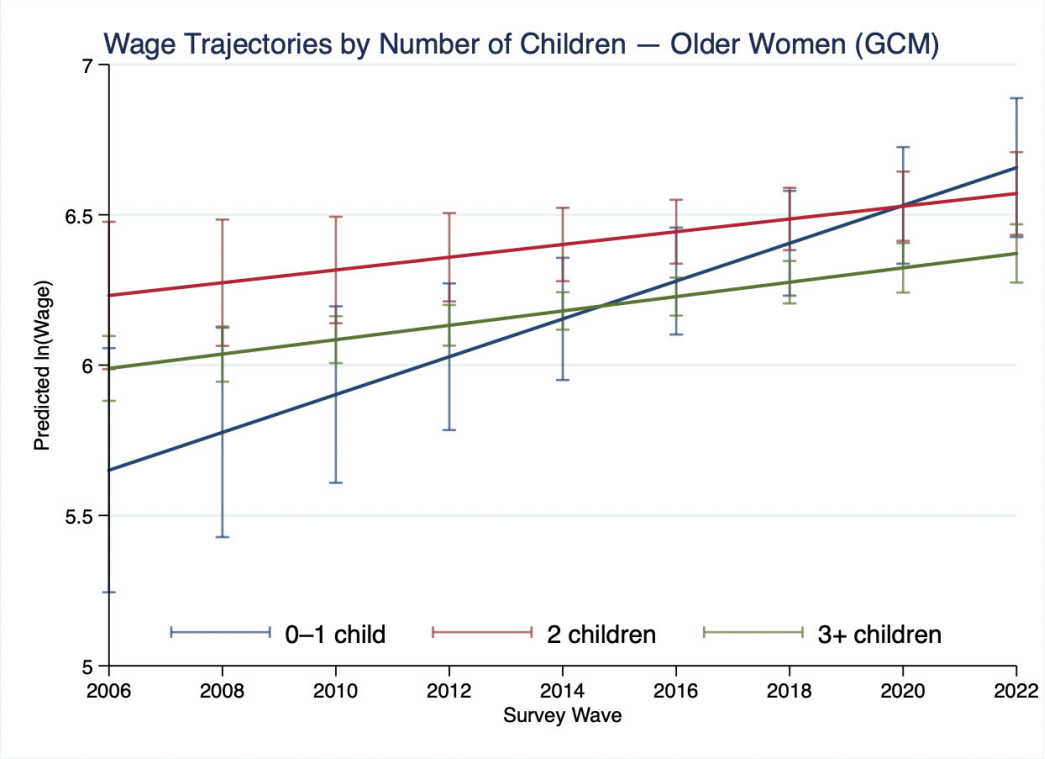
Note. Standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Figure 3 illustrates how wage trajectories among older women diverge according to the number of children over the observation period from 2006 to 2022. Women with zero or one child exhibit the steepest upward wage trajectory across survey waves, while those with two children show a higher starting point but a comparatively flatter rate of growth, and those with three or more children display the most minimal wage growth throughout the observation period. By the end of the panel, the wage trajectory of the zero-to-one-child group converges with and ultimately surpasses those of the higher-parity groups, despite beginning from the lowest initial wage level.

The steep upward trajectory of the zero-to-one-child group suggests that older women who remain in the labor market with fewer children are more likely to be positioned in jobs where wages can be maintained or improved over time. This pattern may reflect the enduring advantages of relatively stable and continuous labor force participation across the life course — accumulated occupational capital that continues to manifest in later life. Conversely, the flatter trajectories observed among women with two or more children are consistent with a history of interrupted or constrained labor market attachment associated with greater caregiving demands.

Crucially, these results do not represent a simple age effect. Rather, they capture the wage trajectories that form as older women remain in the labor market over time, and demonstrate that these trajectories are systematically differentiated by number of children. Number of children does not determine where older women start in terms of wages — but it shapes how far they are able to go. In this sense, fertility history functions not as a fixed wage penalty, but as a structural constraint on the capacity for wage growth in later life.

Figure 3
Predicted ln(Wage) Trajectories by Number of Children Among Older Women



Discussion

The findings of this study offer several important insights into the relationship between fertility history and wage outcomes in later life. Taken together, the results from the random effects, fixed effects, and growth curve models suggest that the gender wage gap in old age is not a phenomenon that emerges anew in later life, but rather the cumulative product of labor market experiences and family-related conditions accumulated across the life course.

The random effects model established that number of children is significantly associated with earned income for both older men and women, suggesting that fertility history carries wage implications that extend into later life for both gender groups. However, the fixed effects model revealed that once unobserved individual heterogeneity is controlled for, this association disappears entirely, indicating that the observed relationship is largely driven by selection processes and stable individual characteristics rather than a within-person causal effect of children on wages. Fertility itself does not appear to causally alter wages at the individual level. Rather, number of children functions as a marker of accumulated life-course conditions—particularly the cumulative labor market consequences of caregiving responsibilities—that are differentially distributed by gender.

This interpretation is most clearly supported by the growth curve model results. Among older men, the number of children had no significant effect on wage trajectories, with no meaningful differentiation across child-count categories. Among older women, however, having two or more children was associated with a significantly slower rate of wage growth over time, while those with zero or one child exhibited the steepest upward trajectory across the observation period. This asymmetry points to a structural, gendered mechanism through which the same life-course factor produces fundamentally different outcomes depending on gender. The

difference is not merely one of effect magnitude; it is a difference in whether the effect exists at all. This suggests that caregiving is not a private or individual matter, but a structural determinant of long-term wage inequality that operates differentially across gender lines.

These results align with a cumulative disadvantage framework, wherein disadvantages accumulated during the early and middle life course—through career interruptions, constrained labor force participation, and occupational segregation associated with caregiving—compound over time and manifest in the wage trajectories of later life (Moen, 1992; 2011). Later-life wage inequality is therefore best understood as a cumulative outcome, not a product of old age per se. Number of children operates as a structural, gendered life-course mechanism that shapes not where women begin in terms of wages, but how far they are able to go.

Conclusions

This study makes three contributions to the literature. First, it extends the analytical focus to later life, reframing old age as a period in which life-course conditions manifest in concentrated form. Second, it demonstrates that the same factor can operate in fundamentally different ways by gender—not as a difference in effect size, but as a difference in whether the effect is present at all. Third, it reveals heterogeneity within the older female population by disaggregating women according to fertility history, uncovering intra-group inequality structures obscured in analyses that treat gender as a binary control variable.

Several limitations warrant acknowledgment. The panel data capture only later-life observations, leaving mediation pathways—including timing of childbirth and the nature of career interruptions—untested. Selective attrition due to the unbalanced panel structure is also possible. Number of children should be understood not as a direct cause of later-life wages but as a condition reflecting cumulative life-course processes. Future research should additionally incorporate qualitative dimensions of work such as employment status and job quality.

Despite these limitations, this study identifies systematic gendered patterns in later-life wage trajectories and demonstrates that the association between fertility and later-life wages is fundamentally cumulative and gendered—shaped by life-course processes that disadvantage women disproportionately and persistently.

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Suboptimal DKA Awareness and Behavioural Gaps Supporting Non-invasive Ketone Monitoring in Elderly Care

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Abstract

Diabetic ketoacidosis (DKA) is a preventable yet life-threatening emergency of diabetes that can lead to multi-organ damage, and avoidable healthcare use when detection is delayed. In community elderly care settings, DKA awareness and ketone monitoring may be limited, while symptoms can remain non-specific or easily overlooked. This proceedings paper reports a pilot survey conducted in Hong Kong within an elderly diabetes community programme led by the School of Nursing and Health Sciences of Hong Kong Metropolitan University. The study recruited 53 older adults with diabetes; 52 completed the questionnaire, yielding a response rate of 98.1%. The questionnaire examined knowledge of DKA, DKA-related symptoms experienced in the prior month, responses to symptoms, and preferred tools for daily diabetes management. The survey showed that 67.3% of respondents had no prior knowledge of DKA. At the same time, 55.8% reported at least one DKA-related symptom, most commonly fatigue or weakness, extreme thirst, diarrhoea, loss of appetite, and nausea. Among those with symptoms, 65.5% neither sought professional support nor communicated with family members. Preference data suggested stronger acceptance of painless breath ketone testing among the younger elderly subgroup, with 70% of participants aged under 65 favouring breath testing. Taken together, the findings indicate a clinically relevant behavioural gap in elderly diabetes care: warning symptoms may be present, but awareness, help-seeking, and timely ketone checking remain insufficient. The paper suggests that education, routine symptom checks, clear guidance on prompt communication when symptoms arise, and non-invasive ketone monitoring deserve stronger integration into community-based elderly diabetes care.

Keywords: diabetic ketoacidosis, elderly care, ketone monitoring, non-invasive breath testing, gerontechnology, digital health, elderly diabetes care in Hong Kong

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Introduction

Diabetic ketoacidosis (DKA) is a life-threatening emergency in diabetes management, and early detection can save lives and reduce healthcare costs. However, DKA symptoms are often subtle or non-specific, making awareness of DKA risk essential to prevent delays in treatment. In addition, euglycemic DKA (EDKA) can occur even when glucose levels appear controlled, underscoring the importance of routine ketone monitoring in diabetes care.

Elderly diabetes management requires special attention, given the significant proportion of undiagnosed cases within this population and the practical challenges of recognising non-specific warning signs in community settings. In elderly care, non-specific symptoms such as fatigue, thirst, nausea, or reduced appetite may easily be overlooked, attributed to ageing, or not treated seriously in time. This creates a potential gap between physiological warning signs and timely recognition of risk.

In view of these challenges, we conducted a pilot survey within an elderly diabetes community program in Hong Kong to assess awareness of DKA risk and preferences for ketone testing. The survey also examined DKA-related symptoms experienced in the prior month and how older adults responded to those symptoms. The purpose was to identify current gaps in awareness, symptom recognition, help-seeking, and monitoring preference that may affect early detection and safer diabetes care in the elderly community.

This proceedings paper reports the findings of that pilot survey and discusses their implications for community-based elderly diabetes care. In particular, this paper suggests education, routine symptom enquiry, clear guidance on prompt communication with healthcare professionals and caregivers when warning symptoms arise, and non-invasive ketone monitoring may help address current behavioural and practical gaps and support more timely risk recognition in elderly care.

Methodology

Participants and Setting

The survey formed part of an elderly diabetes community project conducted in Hong Kong from April 2024 to May 2025 in collaboration with the School of Nursing and Health Sciences of Hong Kong Metropolitan University. Eligible participants were aged 60 years or above and had been diagnosed with diabetes. The programme recruited participants across five districts in Hong Kong: Ap Lei Chau, Aberdeen, Tseung Kwan O, Lok Fu, and Sheung Shui.

Fifty-three participants were recruited, and 52 completed the questionnaire, yielding a response rate of 98.1%. The median age was 70 years, with an age range of 60 to 90 years. The sample was predominantly female, comprising 79% women and 21% men (Table 1).

Survey Design

The questionnaire was designed around four. The first question addressed knowledge of DKA. The second focused on DKA-related symptoms experienced in the prior month. The third examined how participants responded when such symptoms were present, including whether they sought professional support or communicated with family members. The fourth explored preferred tools for daily diabetes management.

Table 1
Participant Profile

Characteristic	Value
Programme period	April 2024 to May 2025
Eligibility	Age 60 years or above; diagnosed diabetes
Recruited participants	53
Questionnaire completions	52
Response rate	98.1%
Districts represented	Ap Lei Chau, Aberdeen, Tseung Kwan O, Lok Fu, and Sheung Shui
Median age	70 years (range 60–90)
Sex distribution	21% male; 79% female

Results

The survey identified several significant gaps in DKA management in elderly community care. First, awareness of DKA was low. Although DKA is a life-threatening acute diabetic emergency, 67.3% of respondents had no prior knowledge of it. This indicates a substantial awareness gap in the elderly community and runs counter to the preventive care principle that early detection supports timely treatment.

Second, DKA-related symptoms were not uncommon. Over half of respondents (55.8%) reported experiencing at least one possible DKA-related symptom in the prior month. The most frequently reported symptoms were fatigue or weakness (32.7%), extreme thirst (26.9%), diarrhoea (19.2%), loss of appetite (17.3%), and nausea (7.7%). These findings suggest that non-specific symptoms occur with notable frequency in daily life, highlighting a critical gap between common assumptions that such warning signs are rare and the actual experiences of elderly individuals living with diabetes.

Third, warning symptoms often failed to prompt timely action. Among respondents who experienced symptoms in the previous month, 65.5% neither sought professional support nor communicated with family members. This finding reveals a clear behavioural gap between symptom experience and help-seeking behaviour. Even when possible warning signs are present, many older adults may not reach out for health support or communicate their concerns in a timely manner.

Fourth, non-invasive breath testing was favoured by younger elderly individuals. Among participants aged under 65, 70% preferred painless breath ketone testing over traditional methods. This suggests that the method of ketone testing may influence willingness to participate in screening. Breath-based, non-invasive approaches may therefore help overcome practical and psychological barriers, supporting more acceptable routine monitoring in elderly diabetes care.

Taken together, these findings point to a clinically relevant gap in elderly diabetes care. Possible warning symptoms are present, but awareness, help-seeking, and timely ketone checking remain insufficient.

Discussion

Recommendations

These findings support four practical recommendations to address the gap identified. First, DKA education should be strengthened for older adults, caregivers, and elderly-centre staff. Because DKA is a life-threatening emergency, limited awareness may delay recognition and timely treatment. Targeted education is therefore needed to improve understanding of DKA risk and to reinforce the importance of early detection in elderly diabetes care.

Second, routine symptom checks should be integrated into practice. The survey showed that DKA-related symptoms were not uncommon, even though they are often non-specific. Regular enquiry about symptoms such as fatigue, thirst, nausea, reduced appetite, or abdominal discomfort may therefore be valuable in routine elderly diabetes care. When these warning signs are present, timely ketone testing should be considered, especially because glucose monitoring alone may not be sufficient in cases such as EDKA.

Third, timely communication should be promoted. The finding that many symptomatic respondents neither sought professional support nor communicated with family suggests that warning symptoms often fail to prompt timely action. Elderly individuals with diabetes should therefore be encouraged to seek help promptly from caregivers and consult healthcare professionals when feeling unwell or experiencing possible warning symptoms.

Fourth, non-invasive screening should be adopted as part of routine care. The preference for painless breath ketone testing among younger elderly individuals suggests that the method of testing may influence willingness to participate in screening. Breath-based, non-invasive approaches may help overcome barriers that can discourage routine monitoring, enabling earlier risk detection.

Table 2
Summary of Key Survey Findings and Recommendations

	Statistics	Key findings	Recommendations
Knowledge of DKA?	67.3% had not heard of DKA	Awareness of DKA is low	Strengthen DKA education for elderly people, caregivers, and elderly-center staff
Any DKA-related symptoms in the past month?	55.8% reported symptoms	DKA-related symptoms were not uncommon	Integrate routine symptom checks and ketone testing into diabetes care
Sought help or discussed symptoms?	65.5% neither sought help nor told family	Warning symptoms are often overlooked and fail to prompt timely action	Encourage prompt contact with HCPs and caregivers when feeling unwell or symptomatic
Preferred daily monitoring tool?	70% of those aged < 65 preferred painless breath testing	Non-invasive breath testing is favored by younger elderly individuals	Painless, non-invasive ketone testing technology can be an invaluable tool to support routine elderly diabetes care management

Benefits of Non-invasive Ketone Testing for Diabetes Care

The benefits of non-invasive ketone testing extend beyond the individual patient. At the patient level, non-invasive ketone testing may enhance safety and quality of life while supporting timely escalation of care. At the caregiver level, it may reduce stress and workload through easier monitoring and support. At the community or elderly-centre level, it may strengthen response by enabling faster recognition and earlier action when warning symptoms arise. At the healthcare system level, it may help reduce late presentation, emergency burden, and avoidable deterioration. These benefits suggest that non-invasive ketone monitoring has practical value across multiple levels of elderly diabetes care.

Moving Forward

Looking ahead, this pilot study highlights important gaps in current diabetes care within the elderly community, and expanding the survey to a broader population may help uncover additional practical challenges that remain unaddressed. Such insights can provide a solid foundation for refining care routines and advancing new standards in elderly diabetes management. At the same time, the next step is not only to deepen understanding, but also to translate these findings into practice. This will require active engagement with healthcare providers, caregivers, community organisations, policy makers, and MedTech companies to explore how cutting-edge technologies can be meaningfully integrated into real-world elderly care settings.

With the advancement of new technologies, routine data being collected via digital platforms will enable respective stakeholders to conduct advanced analytics, generating novel metabolic insights, supporting the shift from prediction to prevention, and further contributing to the digital health transformation by enabling more tailored pathways to healthy longevity.

Finally, the findings from this pilot study underscore the importance of broad collaboration across healthcare, academic, community, policy, MedTech, and elderly-service sectors. Joint efforts that combine education, monitoring practices, effective communication, and the integration of new technologies can strengthen early recognition of metabolic risks and warning signs, enable timely responses, and ultimately help bring the best health outcomes for older people living with diabetes.

Figure 1

Application of Non-invasive Breath Ketone Testing in Elderly Community

Note. Fieldwork photo from the elderly diabetes community project conducted in collaboration with the School of Nursing and Health Sciences, Hong Kong Metropolitan University.

Conclusion

This pilot survey underscores persistent gaps in DKA awareness, symptom recognition, help-seeking, and ketone monitoring within elderly community care. Warning signs may be present, yet timely recognition and response remain insufficient. Addressing these gaps requires strengthening education, embedding routine symptom checks, and ensuring clear pathways for communication with caregivers and healthcare professionals. Integrating painless, non-invasive ketone testing into routine diabetes care may represent a feasible and scalable approach to improving early detection.

When embedded in elderly care pathways, such technology can empower older people living with diabetes, ease the burden on families and caregivers, and support healthcare professionals in delivering more timely and effective care. At a broader level, community adoption may facilitate earlier medical attention, help avoid prolonged hospitalizations through timely treatment, and generate long-term cost benefits for health systems. Notably, these benefits may also extend to older people with undiagnosed diabetes, enabling earlier detection and intervention. Beyond immediate clinical gains, such strategies contribute to a shift from reactive prediction to proactive prevention, fostering healthier longevity and reinforcing the collective responsibility of communities to safeguard the wellbeing of their aging populations.

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Declaration of Generative AI and AI-Assisted Technologies in the Writing Process

The authors declare that OpenAI's ChatGPT and Microsoft Copilot were used to assist in organising, drafting, and refining the language of this manuscript based on author-provided study materials, including the approved conference presentation and accepted abstract. The use of AI was limited to structural drafting, language development, and editorial support. The authors reviewed, revised, and approved the final manuscript and take full responsibility for the study design, data, findings, interpretations, and conclusions.

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Towards Sustainable Digital Inclusion: Community-Based Practices for Older Adults in Urban China

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Abstract

This study explores community-based digital inclusion practices for older adults in urban China, with a focus on Suzhou. Despite national efforts to promote digital equity, gaps remain in local service implementation. Integrating social support, social capital, and social practice theories, the research examines practices across six districts in Suzhou. Data from policy documents, local reports, and case studies were analysed to evaluate how services provide support, foster social capital, and shape digital use. Findings show that current services effectively offer instrumental support and basic training but lack strategies to build bridging social capital or shift older adults' perceptions of technology. The common one-on-one tutoring model supports skill acquisition but isolates learners, limiting peer connections and weakening the sustainability of digital practices. This study highlights the importance of community-level social dynamics in digital inclusion. It argues for a shift from service delivery to an ecosystem-building approach that encourages peer networks and fosters positive digital identities among older adults. These insights contribute to the understanding of sustainable digital inclusion in ageing societies.

Keywords: digital inclusion, older adults, community-level

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Introduction

Digitisation has fundamentally restructured the socio-economic landscape, mediating essential services from fintech to healthcare. While these advancements promise efficiency, they often exacerbate the digital divide, particularly among older adults whose technological adoption is frequently hindered by cognitive constraints and low self-efficacy (Hunsaker & Hargittai, 2020). This issue is critical in China, where rapid digital transformation intersects with profound demographic ageing. By 2025, China's population aged 60 and above reached 323.38 million (23.0% of the total), signalling its transition into a moderately ageing society (National Bureau of Statistics of China, 2026). At the same time, digital systems have increasingly become the default mode for public administration and everyday consumption. This shift has created new forms of exclusion for older adults. Nearly half of this population remains offline. Internet penetration among seniors has plateaued at 52.0% (China Internet Network Information Centre, 2025). This trend poses a significant challenge to social sustainability.

Current scholarship increasingly views digital inclusion not merely as a technical hurdle, but as a socially embedded process (Helsper, 2021). While China has issued 37 national policy documents and 262 accessibility standards by late 2025 to foster "smart elderly care," a "last-mile" gap persists between macro-policy and community-level implementation. Research suggests that digital engagement is heavily contingent upon social capital and the quality of local support networks (Xie et al., 2021). However, many interventions remain narrowly focused on instrumental support. They often overlook the psychological and relational conditions that shape digital participation. These include technological anxiety and the role of intergenerational social support. Such factors are critical to sustained engagement and the development of long-term digital proficiency (Vroman et al., 2020).

To address this implementation gap, this study examines community-based digital inclusion practices in urban China. Drawing on social support theory, social practice theory and social capital theory, the study explores how local service arrangements enable or constrain digital adoption among older adults. It aims to move the discussion beyond a top-down service delivery model. Instead, it highlights the importance of building sustainable local ecosystems that support resilient digital identities in later life.

Literature Review

Digital inclusion in later life is increasingly recognised as a socially embedded process shaped by support relationships, networked resources and everyday practices (Helsper, 2021; Xie et al., 2021). However, existing research has paid limited attention to how community-based arrangements transform short-term assistance into sustained digital participation. To address this gap, this study integrates social support theory, social capital theory and social practice theory into a unified analytical framework.

Social Support Theory explains the forms and functions of assistance that older adults receive in the process of digital adaptation. Classic work distinguishes instrumental, informational, emotional and appraisal support (House, 1981). In the context of digital inclusion, instrumental and informational support provide practical guidance, such as teaching device use or solving operational problems, whereas emotional and evaluative support reduce frustration, strengthen confidence and affirm competence (Vroman et al., 2020). This distinction is important because many digital inclusion interventions remain focused on functional help while neglecting the psychological conditions required for sustained learning and continued use. Social support also

varies by source. Informal networks, such as family members and peers, often provide trust-based and affective support, whereas formal networks, such as community organisations and service providers, offer structured and professional assistance. These forms of support may operate through both stress-buffering and main-effect mechanisms, reducing exclusion while also promoting broader well-being and engagement (Cohen & Wills, 1985).

Whereas social support theory clarifies the nature of assistance, social capital theory explains the structure of relationships through which such assistance becomes available. Social capital is commonly understood in terms of network connections, reciprocity norms and trust (Putnam, 2000; Woolcock & Narayan, 2000). In the context of elderly digital inclusion, these dimensions are highly relevant. The structural dimension concerns whether older adults are embedded in supportive family and community networks. The relational dimension refers to norms of reciprocity that sustain repeated helping behaviours. The cognitive dimension centres on trust, which is especially important for reducing perceived risk in online environments. Social capital can be further differentiated into bonding and bridging forms. Bonding capital, typically found in close family ties, provides immediate support and emotional security. Bridging capital, often formed through community programmes and weak-tie networks, expands access to new information, services and learning opportunities (Putnam, 2000; Woolcock & Narayan, 2000). Sustainable digital inclusion depends on both private family support and broader community-based relational resources.

To examine how digital engagement becomes durable in everyday life, this study also draws on social practice theory. Rather than treating technology use as an individual choice, practice theory understands participation as the ongoing performance of socially organised practices (Reckwitz, 2002; Schatzki, 2002; Shove et al., 2012). Following Shove et al. (2012), this study focuses on three elements: materials, competences and meanings. Materials refer to devices, internet access and community spaces that make digital participation possible. Competences refer to the practical know-how developed through repeated use and guidance. Meanings refer to the symbolic significance attached to technology, including whether older adults view digital participation as empowering or burdensome. This perspective is particularly valuable because it shifts attention from one-time adoption to the stabilisation of digital practices in daily life.

Although these three theoretical traditions have each been widely applied, they are rarely integrated in studies of elderly digital inclusion. Existing research has primarily examined older adults' digital inclusion in relation to individual capability, interpersonal or family-based support, and broader structural provision such as access, services and inclusion policy (Helsper, 2021; Hunsaker & Hargittai, 2020; Vroman et al., 2020). Less is known about how different forms of support, types of social capital and elements of practice interact at the community level to produce sustainable digital participation. This represents an important gap, particularly in rapidly ageing and highly digitalised urban contexts.

Accordingly, this study proposes an integrated framework for analysing how community-based support enables sustained digital inclusion among older adults. Social support theory identifies the forms of assistance required, especially the shift from functional support to emotional and evaluative support. Social capital theory explains the network structures that shape access to such support, particularly the interplay between bonding and bridging capital. Social practice theory examines whether materials, competences and meanings are aligned in everyday life. Together, these perspectives suggest that digital inclusion becomes sustainable only when older adults receive adequate support, are embedded in trustworthy and resource-rich networks and

are able to incorporate digital technologies into meaningful daily practices. This framework guides the case analysis of community-based digital inclusion practices in urban China.

Methodology

This study employs a multiple-case design to examine digital inclusion practices for older adults in urban China. Suzhou was selected as the research site because its ongoing digital transformation, diverse community structures, and relatively rapid population ageing provide a suitable context for examining age-related digital divides. To capture variation across urban contexts, the study covers six districts in Suzhou: Gusu District, Huqiu District, Wuzhong District, Xiangcheng District, Suzhou Industrial Park, and Wujiang District. These districts represent distinct urban contexts, including the historic urban core (Gusu), high-tech development zones (Suzhou Industrial Park and Huqiu), established residential and mixed-use areas (Wuzhong and Xiangcheng), and a rural–urban transition zone (Wujiang). This district-level coverage supports a broad analytical scope and captures variation across different community contexts.

Data were collected from four sources: (1) official policy documents obtained from government archives; (2) authoritative media reports offering longitudinal coverage of digital inclusion initiatives; and (3) community WeChat official accounts documenting grassroots activities. The dataset includes materials published up to June 30, 2025. After applying screening criteria to remove duplicate and incomplete records, the final dataset includes 133 valid cases. This sample set provides sufficient coverage to capture the local characteristics of Suzhou and to identify broader tendencies relevant to digital inclusion in urban China.

Content analysis was employed to examine the dataset through a three-stage procedure. First, a theoretically grounded coding framework was developed based on three established perspectives. Drawing on social support theory, four dimensions were specified: instrumental support (direct assistance), informational support (knowledge and advice), emotional support (empathy and encouragement), and appraisal support (feedback and affirmation). Based on social capital theory, a distinction was made between bonding capital (ties with family and close friends) and bridging capital (connections with community members and volunteers). From social practice theory, three additional dimensions were identified: materials (hardware, software, and facilities), competencies (skills and confidence), and meanings (motivations and attitudes toward technology use). Second, each of the 133 cases was subjected to systematic textual coding. In addition to the identification of each dimension, its intensity was assessed using an ordinal scale of high, medium, low, or absent. In doing so, a more nuanced evaluation of variation across cases was achieved. Third, a cross-case comparative analysis was conducted to synthesise the coding results. Through this process, recurring patterns of digital inclusion in Suzhou were identified, while local strengths and broader systemic shortcomings were also revealed. Overall, qualitative case narratives were transformed into a structured dataset through this multi-dimensional analytical strategy, thereby providing a robust foundation for the subsequent findings.

Results

The findings reveal substantial district-level variation in the design and delivery of digital inclusion services for older adults, although a limited emphasis on appraisal support was evident across all six districts. Service models were shaped by local institutional arrangements and resource endowments, producing distinct patterns of intervention. The Suzhou High-tech

Zone primarily focused on foundational digital skills through one-to-one and hands-on teaching. Gusu District presented a more diversified and culturally embedded service portfolio, including innovative and activity-based formats. Xiangcheng District emphasized the combination of party-building leadership and digital empowerment, with relatively strong community interaction and interest-oriented learning. The Industrial Park relied more heavily on collaborations with enterprises and university volunteers, giving its services a comparatively scaled and professionalised character. Wuzhong District foregrounded system-level integration through smart eldercare platforms and age-friendly digital infrastructure. Wujiang District, by contrast, was characterised by micro-classroom provision in rural communities, with an emphasis on anti-fraud education and basic smartphone use. Despite these contextual differences, formal recognition of older adults' learning progress and achievements remained weak throughout, making the lack of appraisal support a shared limitation across districts. Beyond the overview of the six districts, the study also identifies the following key insights.

Uneven Support Structures

The findings reveal a markedly uneven support structure, in which instrumental and informational support were consistently well developed, whereas emotional and appraisal support remained comparatively limited (Figure 1). Instrumental and informational support were coded as high in more than 95% of the 133 cases. Most initiatives provided concrete operational assistance, such as guidance on mobile payment, online medical registration, and WeChat use, alongside practical information on app functions and fraud prevention. These findings suggest that community-based digital inclusion efforts in Suzhou have been highly effective in addressing older adults' immediate functional and informational needs.

By contrast, emotional support was substantially weaker. Only around 30% of cases were coded as high on this dimension, with most falling into the medium or low categories. Emotional support, where present, was typically inferred from indirect descriptions, such as volunteers' patience or older adults' expressions of satisfaction, rather than being embedded in a systematic care-oriented design. Appraisal support was even more limited, with the majority of cases coded as low or absent. Only about 10% of cases included explicit recognition mechanisms, such as certificates or formal commendation, for example through community-level certificates and completion ceremonies.

Figure 1

Distribution of Emotional and Appraisal Support Across Cases

Note. The figure presents the number of coded cases at four levels of support provision (high, medium, low, and absent). Emotional support and appraisal support were coded based on the presence and intensity of supportive elements identified in each case.

Taken together, these results indicate that current community services have prioritized skill training and information dissemination while paying insufficient attention to emotional care and achievement recognition.

Uneven Social Capital

The findings also indicate that community-based digital inclusion initiatives were more effective in strengthening bonding capital than in fostering bridging capital. Bonding capital, referring primarily to older adults' connections with family members and close acquaintances, was coded as medium or high in approximately 85% of the cases. This pattern reflects the strong emphasis placed on communication-related digital skills, such as WeChat video calls and voice messaging, which enabled participants to maintain or enhance family contact through everyday digital practices.

By contrast, bridging capital, which refers to the formation of weaker ties among older learners, volunteers, and other community members, was considerably less developed. Its strength was closely associated with the organisational format of the training. Cases relying on one-to-one instruction were typically coded as low on this dimension, as they offered limited opportunities for peer interaction. In contrast, cases incorporating group learning, interactive games, or WeChat group building were more likely to achieve medium or high levels of bridging capital. Overall, more than 60% of cases were coded as low or medium in bridging capital, suggesting that most services did not effectively promote horizontal social networks within the older population.

These results suggest that current service provision has been successful in reinforcing family-based ties, but has paid insufficient attention to the deliberate cultivation of weaker community connections.

Practical Orientation in Social Practice

The analysis shows clear variation across the three elements of social practice. Materials and competencies were consistently well developed. Meanings remained comparatively underarticulated. The materials dimension was coded as high in the vast majority of cases, as most initiatives relied on older adults' own smartphones, widely used applications, and accessible community-based venues. Competencies were likewise predominantly coded as high, since training activities were largely designed to address practical operational problems, and participants' immediate difficulties were typically resolved through hands-on instruction.

By contrast, the meanings dimension was more often coded as medium. In most cases, the underlying message was primarily utilitarian, emphasising that digital skills were useful for everyday life, rather than fostering deeper orientations such as digital confidence, technological belonging, or a positive sense of digital identity. Only a limited number of cases were coded as high on this dimension. For example, some initiatives explicitly conveyed the idea that older adults could actively participate in, and even help shape, digital life through intergenerational learning programmes and empowering community slogans.

These findings indicate that current services have established a relatively solid foundation in terms of material access and practical skill development, but have been less effective in cultivating affirmative meanings around digital participation.

Integrated Service Design

A small number of high-performing cases demonstrate that integrated service design can generate more comprehensive outcomes in older adults' digital inclusion. These cases achieved high scores across multiple dimensions, particularly emotional support, appraisal support, bridging capital, and meanings. For example, these initiatives combined practical training with recognition, emotional engagement, intergenerational interaction, volunteer support, and the message that technology can empower and support older adults.

These cases shared several common features, including group-based or intergenerational interaction, symbolic forms of recognition, active emotional feedback, and the communication of values that extended beyond instrumental usefulness. Their balanced performance across theoretical dimensions suggests that digital inclusion is more effective when service provision moves beyond isolated skill training and adopts a multidimensional empowerment approach.

Service Format and the Accumulation of Social Capital

Emotional and appraisal support appeared to be positively associated with bridging capital, with service format playing a decisive role in shaping these outcomes. Cases organised around one-to-one instruction and some home-based training activities, were typically characterised by low or absent bridging capital. Although this format sometimes generated a moderate level of emotional support through individualized attention, appraisal support was almost entirely absent. In contrast, group- or classroom-based formats, including community training sessions and senior learning programs, more often produced medium levels of bridging capital, while also enhancing emotional support through shared interaction. However, appraisal support remained limited in most of these cases. The strongest overall performance appeared in highly interactive or ritualised formats, such as certificate ceremonies, intergenerational activities, and fun competitions. In these cases, bridging capital frequently reached a high level, and both emotional and appraisal support were correspondingly stronger.

These patterns indicate that the cultivation of bridging capital depends heavily on participatory and interaction-oriented service design. One-to-one skills instruction may be effective for targeted teaching, but it does little to foster horizontal ties among older adults. By contrast, formats involving group learning, intergenerational co-creation, public recognition, and opportunities for shared participation are more conducive to the development of weaker social ties, while simultaneously strengthening emotional engagement and evaluative affirmation. This suggests that future services should move beyond one-way transmission and adopt a more collaborative approach to digital inclusion, in which older adults engage as learners and community members.

Discussion

This study advances current understandings of digital inclusion by showing that community-based services for older adults vary across local institutional arrangements, resource endowments, forms of support, network relations, and the meanings they generate in practice. Consistent with prior research, digital inclusion is better understood not as a one-off outcome of access or adoption, but as a socially embedded and practice-based process shaped by the interaction of support, capital, and everyday routines (Seifert et al., 2021; van Deursen, 2020).

The findings show that current initiatives focus mainly on instrumental and informational support, with emotional reinforcement and achievement recognition remaining underdeveloped. This confirms that many digital inclusion services still operate through a functional logic centred on immediate skill acquisition. However, recent research suggests that later-life digital engagement depends on operational assistance, confidence, encouragement, and supportive learning environments (Quan-Haase et al., 2018; Tsai et al., 2022). In the present study, emotional support was often implicit rather than systematically designed, and appraisal support was absent in most cases. This imbalance helps explain why skill acquisition may not automatically translate into sustained engagement. Without positive feedback and recognition, older adults may acquire basic competences while remaining uncertain about their ability to participate independently in digital life.

The findings further suggest that current services are better at reinforcing close and familiar relationships than at cultivating broader and more diverse social connections. Communication-oriented activities, especially those involving WeChat and video calls, clearly reinforced family-based ties. Yet weaker ties among older learners, volunteers, and community actors remained underdeveloped, particularly in one-to-one instructional formats. This matters because digital inclusion is sustained through intimate support from family members and broader networks that facilitate repeated learning, peer exchange, and access to new resources (Ariztía, 2017; Welch & Yates, 2018). Recent studies similarly show that social connectedness and digitally mediated participation are closely intertwined in later life, and that peer-based or community-based engagement can reduce exclusion more effectively than individualized teaching alone (Hunsaker et al., 2023; Seifert et al., 2021). The results therefore suggest that service design should be assessed not only in terms of teaching efficiency, but also in terms of its capacity to generate sustainable relational infrastructures.

The findings highlight that material provision and competence development are important foundations, but by themselves they do not guarantee sustainable digital inclusion. Most cases performed well in providing devices, accessible settings, and practical know-how, but the meanings attached to digital participation were often framed narrowly in utilitarian terms. In many services, technology was presented as useful for solving everyday problems, but less often as a source of autonomy, belonging, or positive digital identity. This aligns with recent work arguing that digital inequalities increasingly reflect differences in the quality, relevance, and continuity of engagement rather than mere first-level access (Büchi et al., 2022; van Deursen, 2020). From a practice perspective, durable digital participation requires material access, competence, and meanings that make technology worth integrating into everyday life (Shove et al., 2012). Where such meanings remain weak, digital practice may remain fragile and vulnerable to interruption.

Importantly, the high-performing cases in this study suggest that sustainable digital inclusion is most likely when support, capital, and practice are jointly addressed. Cases involving intergenerational interaction, symbolic recognition, active emotional feedback, and positive value framing achieved more balanced outcomes across emotional support, appraisal support, bridging capital, and meanings. These findings resonate with recent scholarship emphasising that age-inclusive digital participation depends on relational, contextual, and identity-related conditions, rather than on skills training alone (Gallistl et al., 2021; Rosales & Fernández-Ardèvol, 2020). The study therefore contributes by showing that digital inclusion among older adults is more appropriately conceptualized as sustainable digital social integration. For policy and practice, this implies that future interventions should move beyond one-way knowledge transmission and develop more participatory, trust-based, and meaning-centred service models.

Conclusion

This study examined how community-based digital inclusion services for older adults are organised and practiced in Suzhou, with particular attention to the interplay of social support, social capital, and social practice. The findings show that while local initiatives have made substantial progress in reducing immediate operational barriers, current service provision remains uneven and primarily skills-centred. Across districts, instrumental and informational support were consistently strong, but emotional and appraisal support were underdeveloped. Likewise, services were more effective in reinforcing bonding capital through family-oriented communication than in fostering bridging capital among peers, volunteers, and broader community actors. From a social practice perspective, materials and competences were generally well established, whereas meanings associated with digital participation were often framed in narrowly utilitarian terms.

These results suggest that digital inclusion for older adults cannot be adequately understood as a matter of access or training alone. Rather, sustainable inclusion depends on whether older adults are supported in using technologies and in developing confidence, recognition, social connectedness, and a positive sense of belonging in digital life. The high-performing cases in this study point to the value of integrated service models. These models combine practical instruction with emotional feedback, symbolic recognition, intergenerational interaction, and affirmative value framing. Together, they can generate more comprehensive outcomes. This indicates that digital inclusion is most effective when conceived as a multidimensional process of social integration rather than a narrow intervention in digital skills.

The study adds to the literature by highlighting how later-life digital inclusion is shaped by local service ecologies and community relations. It also contributes to practice by highlighting the limitations of one-way, transmission-based service models and the need for more participatory and relational approaches.

Several limitations should be acknowledged. The study focuses on one city and is based primarily on documented community cases, which may not fully capture older adults' subjective experiences or longer-term outcomes. Future research could incorporate interviews, longitudinal designs, and comparative analysis across cities or rural–urban settings to test the broader applicability of the findings. Despite these limitations, the findings indicate that sustainable digital inclusion in later life depends on more than access and skills alone. It also relies on the broader social conditions that support digital participation.

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Aging Under Crisis: The Compounding Challenges of Healthy Aging in Post-coup Myanmar

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Abstract

Despite the growing recognition that healthy aging is a multidimensional phenomenon shaped by social, economic, and relational conditions, very little research has examined how older adults experience and understand aging well in contexts of sustained political crisis. This study addresses that gap through qualitative inquiry in Myanmar, a setting where prolonged instability since 2021 has placed the foundations of healthy aging under considerable strain. Guided by a constructivist epistemology, semi-structured interviews were conducted with 26 retirees across urban and rural settings. Data were analyzed using inductive thematic analysis, through which three themes were constructed: undermined psychological wellbeing, in which chronic fear and uncertainty eroded participants' sense of inner peace; threatened economic and physical security, reflecting the collapse of healthcare access and financial stability; and disrupted social roles and family bonds, capturing participants' grief over their inability to fulfill the caregiving and relational roles central to their sense of aging well. As one of the first studies to explore the lived experience of healthy aging in Myanmar's crisis context, the findings carry important implications for how humanitarian responses conceptualize and address the needs of older adults in conflict-affected settings.

Keywords: aging, healthy aging, Myanmar, political crisis, gerontology

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Introduction

In 2021, Myanmar experienced a significant political transition that ushered in a period of profound and ongoing instability (Fan et al., 2024; Kyriakou et al., 2025). Widespread civil disruption, economic deterioration, the weakening of public services, and large-scale displacement have had severe consequences for civilian life (Donnellan et al., 2021; Fan et al., 2024; United Nations Office for the Coordination of Humanitarian Affairs, 2023). For the country's older adults, these conditions compound the vulnerabilities already inherent to later life, dismantling the social, economic, and relational structures on which aging well depends. Yet despite the breadth of humanitarian scholarship on crisis-affected populations, the subjective experience of aging under political upheaval remains largely unexplored. Research on older adults in crisis settings has grown but remains dominated by quantitative assessments of material vulnerability, offering limited insight into how older adults themselves make sense of what it means to age well when the conditions for doing so have been fundamentally disrupted (Fan et al., 2024; HelpAge International, 2025; van Boetzelaer et al., 2023). This is a significant omission. Humanitarian responses designed without an understanding of how older adults interpret and construct meaning around their own aging risk missing what matters most to those they seek to support (Park et al., 2025). The frameworks through which older people interpret and give meaning to their own aging are not peripheral to their wellbeing; they are foundational to it (Park et al., 2024; Park et al., 2025). Where those frameworks are culturally specific, as they are in Myanmar, the inadequacy of generic, externally imposed models carries still greater weight.

Literature Review

Conceptualizing Healthy Aging

The concept of healthy aging has evolved substantially, shifting from a narrow biomedical focus toward a broader, multidimensional understanding. Rowe and Kahn's (1997) influential model proposed that healthy aging comprises low probability of disease, high cognitive and physical functioning, and active engagement with life. While widely adopted, the model has attracted critique for its individualist assumptions and its embeddedness in Western conceptions of productivity and independence as measures of a good old age (Donnellan et al., 2021; Katz & Calasanti, 2015). The World Health Organization (2015) extended the framework through its concept of active aging, foregrounding the structural conditions, social, economic, political, and physical, that enable or constrain older adults' capacity for wellbeing. Beard et al. (2016) similarly argued that healthy aging is constituted as much by enabling conditions as by individual characteristics. This structural orientation is foundational to the present study: when those conditions are dismantled by political crisis, the question of whether healthy aging remains achievable becomes deeply pressing. Cultural context further shapes what aging well means. In East and Southeast Asian settings, filial piety positions older adults as members of relational networks whose dignity and wellbeing are constituted through intergenerational bonds of care and reciprocity (Ikels, 2004; Mehta, 1997). For older adults in Myanmar, Theravada Buddhist values of inner equanimity, acceptance, and spiritual practice are woven into everyday understandings of what it means to age with grace and moral worth (Latt et al., 2016). Analytical frameworks that fails to attend to these cultural dimensions will produce an incomplete picture of healthy aging in this context (Park et al., 2025). Taken together, these theoretical developments point toward a conception of healthy aging that is structural, relational, and culturally embedded. What they do not yet fully illuminate is what happens when the structural conditions for aging well are not merely inadequate but actively

dismantled, and when the cultural resources through which older adults navigate that process are themselves under strain. Myanmar's post-2021 context presents precisely this challenge, making it an unusually important site for extending existing theory.

Aging in Crisis Settings and Myanmar's Post-2021 Context

Research on older adults in conflict and humanitarian settings documents compounding and often invisible disadvantages: mobility limitations impede service access; chronic conditions require continuity of care that crisis contexts rarely provide; financial reserves are quickly exhausted; and older adults frequently assume caregiving roles for grandchildren whose parents have been displaced (Fan et al., 2024; HelpAge International, 2025; Hutton, 2008). Despite this, older adults are systematically underrepresented in humanitarian programming (van Boetzelaer et al., 2023). Beyond material vulnerability, the disruption of social roles and relational functions through which older adults construct meaning in later life carries significant psychological consequences that quantitative indicators rarely surface (Fan et al., 2024; Grenier et al., 2017; United Nations High Commissioner for Refugees, 2025). Myanmar's post-2021 context illustrates these dynamics acutely. Its healthcare system has been weakened by workforce disruption and constrained humanitarian access (World Health Organization, 2025); the economy has contracted sharply, placing basic goods beyond reach for many (World Bank, 2023); and family networks have been fractured by displacement and migration, severing the intergenerational bonds that, in Myanmar's cultural context, constitute the relational fabric through which older adults understand their own worth (Ikels, 2004; Mehta, 1997; United Nations Office for the Coordination of Humanitarian Affairs, 2023). What this body of evidence has yet to adequately address is how older adults themselves make sense of aging well within such conditions, and how culturally specific frameworks of dignity and meaning shape that understanding. The purpose of the present study, elaborated below, is to address that gap directly.

Purpose of the Study

Older adults in crisis settings face compound vulnerabilities that existing quantitative evidence captures only partially (United Nations Population Fund, 2012; van Boetzelaer et al., 2023). How they make sense of aging well under conditions of sustained upheaval, and how that meaning is shaped by the cultural frameworks through which they understand later life, remains an underdeveloped area of inquiry. Where those frameworks are as culturally specific as they are in Myanmar, generic analytical models are unlikely to surface what matters most to older adults themselves. Myanmar's post-2021 context is therefore both a compelling and an urgent site for qualitative investigation: a setting where the structural conditions for healthy aging have been comprehensively disrupted, and where Buddhist values of equanimity and deeply relational conceptions of dignity and worth demand an approach attentive to cultural particularity. The present study responds to this need by asking: How do older adults in Myanmar understand and experience healthy aging amid ongoing socio-political crisis?

Methods

Research Design

This study was guided by a constructivist epistemology, which holds that knowledge is actively constructed through the interactions between researchers and participants rather than discovered as an objective reality (Creswell & Poth, 2018). From this standpoint, meaning is

plural, situated, and co-produced through the research encounter, making constructivism particularly well-suited to a study concerned with how older adults make sense of their own aging experiences. Consistent with this position, the study adopted a qualitative design, which is especially appropriate when the aim is to explore complex, context-dependent phenomena from the perspective of those who live them (Braun & Clarke, 2006; Denzin & Lincoln, 2018). The lived experience of aging under political crisis is precisely this kind of phenomenon: deeply subjective, culturally embedded, and resistant to capture through standardized measures. The study further drew on an interpretive sensibility in its orientation to the data, seeking to understand not only what participants experienced but how they interpreted and made meaning of those experiences within their own cultural and relational frameworks (Gubrium & Holstein, 2000).

Participants and Sampling

Participants were 26 retirees residing in Myanmar at the time of data collection. Purposive sampling was used to identify individuals who were of retirement age, had lived through the onset of the political crisis, and were willing and able to engage in an interview, with participants drawn from both urban and rural settings to ensure diversity of experience and context. Given the sensitive political climate and the practical constraints of conducting research in Myanmar, a snowball sampling approach was also employed, with initial participants introducing the research team to further potential participants within their networks. The first and second authors, both Myanmar nationals with established community ties and an intimate understanding of the local socio-political landscape, served as primary gatekeepers in this process, leveraging their cultural proximity and existing relationships to gain access to participants who might otherwise have been unreachable to external researchers. This approach was particularly important in a context where trust is not easily established across unfamiliar research relationships. All participants provided informed consent prior to their involvement, and confidentiality was maintained throughout through the use of pseudonyms and secure data management practices. Sample characteristics are summarized in Table 1.

Table 1
Participant Sample Characteristics (N = 26)

Characteristic	Category	n (%)
Gender	Male	14 (53.8%)
	Female	12 (46.2%)
Age Group	60–69 years	11 (42.3%)
	70–79 years	10 (38.5%)
	80+ years	5 (19.2%)
Residence	Urban	13 (50.0%)
	Rural	13 (50.0%)
Living Arrangement	With family	19 (73.1%)
	Living alone	7 (26.9%)
Prior Occupation	Government service	10 (38.5%)
	Private sector	9 (34.6%)
	Self-employed / farming	7 (26.9%)
Total		26 (100%)

Note. Occupational categories reflect participants' primary employment prior to retirement.

Data Collection

Data were collected through semi-structured interviews guided by questions covering participants' understandings of aging well, their daily experiences since the onset of the crisis, changes to their health, and the impact on their family relationships and social roles. All interviews were conducted by the first and second authors, both fluent Burmese speakers and Myanmar nationals, enabling them to build rapport quickly, attend to culturally embedded meanings, and respond sensitively to the emotional dimensions of conversations about aging under upheaval. Interviews were conducted in person in Burmese throughout, lasted approximately 50 minutes, and were audio-recoded with participant consent.

Following data collection, the first author transcribed recordings verbatim in Burmese, then translated them into English, with the second author reviewing translations for clarity and consistency. This in-team approach to transcription and translation, rather than outsourcing, preserved the integrity and nuance of participants' accounts across the move from spoken Burmese to written English.

Data Analysis

Transcripts were analyzed using inductive thematic analysis following Braun and Clarke's (2006) six-phase framework, allowing themes to be constructed from participants' own words rather than imposed from predetermined categories. The process moved from familiarization and initial coding through to the development, review, and refinement of themes in iterative discussion across the research team. To strengthen trustworthiness, researchers coded independently before reconciling interpretations, and peer debriefing was used to interrogate

assumptions. Reflexivity was maintained throughout, with particular attention to how the first and second authors' proximity to the research context may have shaped the analytical process.

Ethical Considerations

Ethical approval for this study was granted by the Institutional Review Board of the International Executive School, Strasbourg, France. All participants provided informed consent prior to their involvement and were reminded of their right to withdraw at any time without consequence. Given the sensitivity of the research context, the protection of participant identities was treated as a priority throughout. Pseudonyms were assigned at the point of transcription, no identifying information was retained in the research record, and all data were stored securely with access restricted to the research team. Interview recordings were deleted upon completion of transcription. Interviewers remained attentive to participants' wellbeing throughout each conversation and were prepared to pause or conclude interviews if signs of distress arose. Reflexivity was maintained as an ongoing practice, with the research team remaining attentive to how their own positionalities and cultural ties to Myanmar may have shaped the conduct and interpretation of the research.

Results

The analysis generated three interpretive themes that together illuminate how older adults in Myanmar make sense of aging well under conditions of ongoing crisis. These themes are not offered as exhaustive or mutually exclusive categories but as overlapping constructs that reflect the mutually reinforcing ways in which participants understood their situation. An overview is provided in Table 2, with each theme explored below through participant accounts. All excerpts have been translated from Burmese into English by the first and second authors.

Table 2
Summary of Themes and Key Manifestations

Theme	Core Concern	Key Manifestations
1. Undermined Psychological Wellbeing	Erosion of inner peace and mental stability regarded as central to aging well	Chronic fear and anxiety; inability to plan; loss of spiritual equanimity; existential uncertainty
2. Threatened Economic and Physical Security	Convergence of material deprivation and healthcare collapse	Loss of income and savings; inability to access medications; disrupted chronic disease management; forced trade-offs between food and healthcare
3. Disrupted Social Roles and Family Bonds	Inability to fulfill caregiving and advisory roles central to dignified aging	Family displacement; reversal of intergenerational support; loss of community networks; grief over diminished social standing

Note. Themes were developed through inductive thematic analysis of 26 semi-structured interviews conducted in Burmese. All excerpts have been translated from Burmese into English by the first and second authors.

Theme 1: Undermined Psychological Well-being

Participants returned repeatedly to inner peace as something foundational to aging well, not a luxury but a precondition. For many, the crisis had made this kind of peace feel permanently out of reach. What was striking was not only the presence of anxiety but a deeper disorientation: a sense that the conditions necessary for the kind of old age they had always imagined had been taken from them. For older adults in Myanmar, where Buddhist frameworks of equanimity and spiritual practice are integral to conceptions of aging with dignity, this was not experienced merely as emotional distress but as a rupture in the very orientation through which one ages well.

> Every morning I used to go to the monastery. That was my time. My quiet time. But since all this happened, even when I sit down and try to be still, my mind just goes everywhere. I think about my grandchildren. I think about what happened to the village down the road. How is an old man supposed to find peace in times like these? I don't know how to be old properly anymore. (U Myint, 68, rural, translated from Burmese)

Theme 2: Threatened Economic and Physical Security

Participants described the collapse of health services, rising medicine costs, and the loss of income not as separate problems but as a single, compounding weight. Growing older had always involved navigating health challenges, but the crisis had stripped away the modest supports through which they had previously managed. What came through was a quiet resignation beneath the pragmatism: they were adapting as best they could, but genuine self-care had become effectively impossible.

> I've had high blood pressure for years. Before, I could just go to the clinic and get my tablets, it wasn't expensive. Now the clinic is sometimes closed, sometimes the medicine just isn't there. And when I do find it, the price has gone up so much. Last month I had to choose: tablets or rice. I bought the rice. What else could I do? But then I lie awake worrying about what's happening inside my body. (Daw Aye, 74, urban, translated from Burmese)

Theme 3: Disrupted Social Roles and Family Bonds

Participants spoke with particular intensity about what the crisis had done to their relationships and to their sense of themselves within their families. Growing older in Myanmar is bound up with specific expectations about contribution, reciprocity, and intergenerational care. Participants had expected to age into roles of gentle authority, as grandparents, as sources of wisdom and stability. The crisis had made many of those expectations impossible to fulfill, and what they described was not simply loneliness but a more fundamental disruption to the relational fabric through which aging well is constituted.

> My daughter has three kids. Before, whenever she needed me, I was there. I'd look after the children, bring food, help with money when I could. Now my pension is worth almost nothing. I can't help them. I just sit here in my house knowing they're struggling and there's nothing I can do. This isn't how I thought I'd be as an old woman. I thought I'd be useful. (Daw Thida, 67, urban, translated from Burmese)

Discussion

This study set out to explore how older adults in Myanmar understand and experience healthy aging amid ongoing socio-political crisis. What the three themes together illuminate is that healthy aging is not simply a matter of individual health behaviour or biological trajectory, but is fundamentally conditioned by the social, political, and relational structures within which people grow old (Akhter-Khan et al., 2022; Beard et al., 2016). When those structures are disrupted, aging well does not merely become more difficult; it becomes, in participants' accounts, something that feels almost conceptually out of reach.

The study makes several contributions to existing theory. The theoretical framework of healthy aging, as extended by the World Health Organization (2015) and Beard et al. (2016), treats wellbeing in later life as multidimensional. What the present findings add is an understanding of how those dimensions interact recursively under conditions of crisis. The loss of psychological equilibrium that participants described eroded their capacity for the very practices, spiritual and social, through which they had always understood themselves to be aging well. This suggests that the relationship between wellbeing dimensions is not merely correlational but constitutive: when inner peace is disrupted, the capacity to manage health, maintain relationships, and inhabit meaningful social roles is diminished alongside it. Existing frameworks tend to treat these dimensions as parallel rather than mutually reinforcing (Katz & Calasanti, 2015), and the findings here suggest that may be a significant limitation in crisis contexts. The cultural specificity of this finding also demands attention. Participants' distress around their inability to maintain spiritual practice is not adequately captured by clinical categories of anxiety (United Nations High Commissioner for Refugees, 2025). Theravada Buddhist frameworks orient older adults toward an inward journey of acceptance bound up with their sense of dignity and moral worth (Lee et al., 2021; Traphagan, 2000). Its disruption constitutes a form of existential displacement that culturally generic humanitarian responses are unlikely to reach (Inter-Agency Standing Committee, 2007). More broadly, participants had not simply lost access to services; they had lost the relational and social roles through which later life becomes meaningful (Grenier et al., 2017; Mehta, 1997). This points toward a reconceptualization of what adequate humanitarian response to the needs of older adults looks like: not as a matter of ensuring survival alone but of attending to the conditions under which people can continue to be who they are.

At the level of practice, the findings reinforce the case for age-sensitive programming that attends to psychological, social, and relational dimensions of wellbeing alongside material needs (HelpAge International, 2025). Mental health support for older adults in crisis settings must engage with culturally specific frameworks of wellbeing rather than applying generic models (Inter-Agency Standing Committee, 2007), and healthcare responses must treat continuity of care for chronic conditions as a priority (World Health Organization, 2025). Theoretically, the study contributes to scholarship challenging Western-centric models of healthy aging by foregrounding the structural conditions and cultural frameworks within which aging is lived (Akhter-Khan et al., 2022; Katz & Calasanti, 2015), and demonstrates the indispensability of qualitative inquiry for understanding these dimensions (Braun & Clarke, 2006; van Boetzelaer et al., 2023).

Limitations and Further Research

The use of purposive and snowball sampling through the community networks of the first and second authors as Myanmar nationals and gatekeepers was a methodological strength that

facilitated access and trust in a difficult research environment. It also means, however, that the sample reflects the social networks available to the research team: those most isolated, most unwell, or outside those networks may have experiences that differ importantly from those documented here. The relational closeness between researchers and participants, valuable for depth, also introduces the possibility that accounts were shaped by that relationship. The study further captures a single moment in a dynamic situation; longitudinal research would offer a richer account of how experiences shift over time. Future studies engaging more systematically with Myanmar's ethnic and geographic diversity, and comparative work across conflict-affected settings in the region, would substantially broaden the evidence base.

Conclusion

This study offers a detailed account of how Myanmar's ongoing political crisis has shaped the lived experience of aging for older adults across the country. Through qualitative inquiry with 26 retirees in urban and rural settings, it illuminates how healthy aging, understood by participants as encompassing inner peace, physical and material security, and the fulfillment of valued social roles, has been rendered experientially unattainable by sustained instability. The three themes constructed through inductive thematic analysis speak to one another, pointing not to discrete hardships but to a comprehensive erosion of the conditions necessary for aging well. Taken together, these findings call for humanitarian and policy responses that recognize the full complexity of older adults' needs in crisis settings and that attend to psychological, material, and relational dimensions of wellbeing alongside immediate survival concerns. Perhaps most fundamentally, the experiences documented here invite a reimagining of what it means to support older adults through crisis: not simply as a matter of keeping people alive, but of preserving the conditions under which they can continue to live with dignity, purpose, and a sense of their own place in the world.

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Understanding Preference for Solitude: A Data-Driven Approach Based on a Dual-Process Architecture

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Abstract

Why do some people actively seek time alone while others prefer constant social contact? We examined this question using behavioral data from 203 older adults in Singapore, measuring 104 aspects of their lives—from daily activity patterns to personality traits to health status. We compared three analytical approaches: (1) traditional factor analysis with ordinary least squares regression, (2) confirmatory factor analysis for construct validation, and (3) a two-stage ensemble method inspired by dual-process theories of cognition. The two-stage approach explained 28% of variance in solitude preference, substantially outperforming traditional methods (13%) and single-model machine learning (21%). Critically, proper hyperparameter tuning revealed that the analytical refinement stage (gradient boosting) added meaningful value beyond initial pattern recognition (random forest), increasing explained variance by 7 percentage points. The strongest predictors were behavioral patterns (hours spent alone, solitary activities) rather than personality traits—extraversion ranked only 15th among 104 predictors. Confirmatory factor analysis validated solitude preference as a distinct construct, separating from loneliness ($r = .42$), social anxiety ($r = .18$), and extraversion ($r = -.36$). These findings advance understanding of solitude as a meaningful individual difference with practical implications for well-being in later life and demonstrate methodological advantages of ensemble methods for complex behavioral data with mixed variable types.

Keywords: solitude preference, dual-process theory, individual differences, factor analysis, ensemble methods, older adults

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Introduction

Background and Motivation

Humans are fundamentally social creatures. We form relationships, seek companionship, and generally thrive on social connection. Yet some people actively choose to spend time alone—not because they lack social skills or suffer from loneliness, but because they genuinely enjoy solitude and find it restorative. Understanding why some people prefer solitude while others seek constant social interaction matters for several reasons.

Americans spend substantial time alone—17% for children to 48% for retirees (Larson, 1990)—which can be enriching or isolating depending on individual preference. Society often stigmatizes solitude, equating it with loneliness, yet understanding healthy solitude is increasingly important for aging populations.

The key insight from previous research: not everyone who spends time alone is lonely, and not everyone who prefers solitude is avoiding others (Burger, 1995). Some people have learned to appreciate the benefits that solitude brings—time for self-reflection, creative pursuits, emotional renewal, and personal restoration. Distinguishing between healthy solitude preference and problematic social isolation requires understanding what predicts this individual difference.

What We Know About Solitude

Previous research shows that solitude can have both positive and negative effects. On the negative side, excessive isolation associates with loneliness, depression, and poorer physical health. People who spend most of their time alone often report feeling bored, passive, and emotionally flat. Adolescents who withdraw socially may struggle with identity development and peer relationships.

On the positive side, self-imposed solitude can promote well-being. Periods alone allow people to engage in necessary self-reflection, work through personal problems, explore creative interests, and restore emotional energy after demanding social interactions. Historical figures from Carl Jung to Virginia Woolf deliberately sought extended periods of isolation to deepen their intellectual and creative work. Abraham Maslow (1970) found that psychologically healthy, self-actualized people often expressed strong preferences for privacy and solitude while also maintaining deep friendships and warm interpersonal relationships. Their preference for solitude reflected self-knowledge and personal growth, not social anxiety or interpersonal problems.

Research Challenges

Understanding who prefers solitude requires addressing conceptual and methodological challenges.

Methodologically, behavioral datasets combine numerical and categorical information, and traditional methods struggle with this combination.

Moreover, traditional regression approaches assume linear, additive relationships: each predictor contributes independently to the outcome. But behavioral phenomena often involve

interactions and nonlinearities. The effect of age on solitude preference might differ for men versus women, or health status might matter more for people living alone. Traditional methods require researchers to specify these interactions in advance; data-driven methods can discover them automatically.

Study Objectives

This study addresses three objectives. First, we validate preference for solitude as a distinct construct using confirmatory factor analysis, testing whether it separates empirically from loneliness, social anxiety, and extraversion. Second, we compare traditional analytical methods (factor analysis with ordinary least squares regression) against modern ensemble approaches for predicting individual differences in solitude preference. Third, we test whether a dual-process analytical architecture—combining parallel pattern recognition with sequential analytical refinement—provides advantages for complex behavioral data with mixed variable types and potential nonlinear relationships.

Theoretical Framework: Dual-Process Architecture

We drew inspiration from dual-process theories in cognitive psychology (Evans & Stanovich, 2013; Kahneman, 2011). These theories propose that human thinking operates through two complementary systems.

System 1 (Fast Thinking) provides rapid, automatic, intuitive processing by quickly recognizing familiar patterns but can make systematic errors.

System 2 (Slow Thinking) provides deliberate, analytical, controlled processing, working step-by-step to check and correct System 1's impressions.

Effective thinking combines both systems.

We designed a two-stage analytical method mirroring this architecture: Stage 1 (Random Forest) captures broad patterns through parallel processing across 300 trees; Stage 2 (Gradient Boosting) corrects systematic biases through sequential processing.

Critical question: Does Stage 2 actually add value when properly configured, or does Stage 1 capture all relevant patterns?

Methods

Participants

We analyzed data from 203 community-dwelling older adults in Singapore (*M* age = 68 years, range 55–89; 58% female). All participants were healthy, independent individuals living in the community (not in institutional care). They completed comprehensive assessments of their psychological characteristics, social relationships, health, and daily activities. The study received ethical approval and all participants provided informed consent.

Measures

Preference for Solitude: We used Burger's (1995) Preference for Solitude Scale, a well-validated 12-item forced-choice measure. Each item presents two statements, and participants choose which better describes them. Example items: "I try to structure my day so that I always have some time to myself" versus "I try to structure my day so that I always am doing something with someone"; "I like to vacation in places where there are few people around and a lot of serenity and quiet" versus "I like to vacation in places where there are a lot of people around and a lot of activities going on"; "After spending a few hours surrounded by a lot of people, I am usually eager to get away by myself" versus "After spending a few hours surrounded by a lot of people, I usually find myself energized and stimulated."

Scores range from 0 (strong preference for social contact) to 12 (strong preference for solitude). Internal consistency in our sample: $\alpha = .71$. Sample distribution: $M = 4.9$, $SD = 2.6$, meaning slightly more people preferred some solitude over constant social contact, with substantial individual variation.

Importantly, this scale measures preference—how much people want to spend time alone when given the choice. It doesn't measure loneliness (feeling isolated and wanting more social contact) or social anxiety (avoiding people due to fear). Previous research shows that people can score high on preference for solitude while also having close friendships and low social anxiety.

Predictor Variables (104 total): We examined 104 different aspects of people's lives, grouped into five categories.

Demographics and Social Context (15 variables): Age, gender (male/female), ethnicity (Chinese/Malay/Indian/Other), marital status (single/married/divorced/widowed/separated), education level (primary/secondary/junior college/polytechnic/university/postgraduate), current living arrangement (alone/with spouse/with children/with others), residential type (public housing/condominium/landed property), whether they employ a foreign domestic worker, height, weight, and household income.

Social Network Characteristics (6 variables): Number of close friends, frequency of family contact, participation in organized social activities (clubs, religious groups, volunteer organizations), social support received from others, social support provided to others, and diversity of their social network (how many different types of people they interact with regularly).

Daily Activity Patterns (22 variables): Hours per week spent alone, with friends, with family, in organized group activities, in solitary leisure (reading, watching television, hobbies), in social leisure (dining out, visiting friends, attending events), and in physical activity. We measured these separately for weekdays versus weekends, yielding 22 specific activity variables.

Health and Functioning (26 variables): Nineteen specific chronic health conditions (hypertension, diabetes, cardiovascular disease, stroke history, arthritis, osteoporosis, respiratory conditions, cancer history, kidney disease, liver disease, and others) plus seven health indicators (self-rated health, physical functioning, activities of daily living, instrumental activities of daily living, pain severity, sleep quality, number of medications taken).

Psychological Characteristics (35 variables): Big Five personality traits (extraversion, neuroticism, openness to experience, agreeableness, conscientiousness) measured using the NEO Five-Factor Inventory; loneliness (UCLA Loneliness Scale, 3-item version); depression symptoms (CES-D short form); life satisfaction; sense of meaning in life; resilience; social anxiety measured via the Interaction Anxiousness Scale; and various other validated psychological constructs.

Analytical Strategy

We compared three analytical approaches to understand which best predicts individual differences in solitude preference.

Approach 1: Traditional Factor Analysis With OLS Regression

This represents the standard approach in behavioral science when faced with many predictors.

Step 1 – Dimensionality Reduction: We applied principal components analysis to the 104 predictors. Numerical variables were standardized (mean = 0, SD = 1). Categorical variables were converted using one-hot encoding (creating binary dummy variables for each category). We retained components with eigenvalues greater than 1.0, yielding 23 principal components that collectively explained 71% of total variance in the predictor space.

Step 2 – Ordinary Least Squares Regression: We regressed solitude preference scores onto the 23 principal components using standard OLS regression. This produces linear predictions where each component contributes additively to the outcome.

Approach 2: Construct Validation via Exploratory and Confirmatory Factor Analysis

To test whether preference for solitude represents a distinct construct or simply reflects introversion, loneliness, or social anxiety, we conducted both exploratory and confirmatory factor analyses.

Exploratory Factor Analysis: We conducted EFA on items from four related scales: Burger's Preference for Solitude Scale (12 items), UCLA Loneliness Scale (3 items), Social Anxiety subscale from the Interaction Anxiousness Scale (5 items), and Extraversion subscale from the NEO Five-Factor Inventory (12 items). This yielded 32 items total. We used maximum likelihood extraction with oblique rotation (promax) to allow factors to correlate naturally. We tested solutions from 1 factor through 4 factors, evaluating each using eigenvalues, scree plots, and interpretability.

Confirmatory Factor Analysis: Based on EFA results and theoretical expectations, we tested a 4-factor model explicitly specifying: (1) Preference for Solitude factor (12 items from Burger scale), (2) Loneliness factor (3 items), (3) Social Anxiety factor (5 items), (4) Extraversion factor (12 items). We evaluated model fit using multiple indices: Comparative Fit Index (CFI $> .90$ indicates acceptable fit), Tucker-Lewis Index (TLI $> .90$), Root Mean Square Error of Approximation (RMSEA $< .08$), and Standardized Root Mean Square Residual (SRMR $< .08$). We also tested alternative models (1-factor, 3-factor) to verify that the 4-factor structure fit better than simpler alternatives.

Approach 3: Two-Stage Ensemble Method

Stage 1 – Random Forest (System 1 Analogue): We trained a random forest with the following specifications: 300 trees, max features per split = $\sqrt{p}$ (square root of number of predictors, ensuring diversity across trees), min samples per split = 10 (preventing overly specific splits), min samples per leaf = 5 (ensuring each terminal node represents generalizable patterns), bootstrap sampling enabled (each tree sees different data sample), out-of-bag scoring enabled (internal validation).

Categorical variables (gender, ethnicity, marital status, education level, living arrangement, residential type) were handled natively through binary splits without requiring numerical encoding. This eliminates researcher decisions about how to encode categories.

Stage 2 – Gradient Boosting (System 2 Analogue): We applied XGBoost to the residual errors from Stage 1—the differences between actual solitude preference scores and Stage 1 predictions. Initial implementations used default hyperparameters and showed minimal improvement (adding only 0.2 percentage points of explained variance), suggesting the approach was not working as intended.

We conducted systematic hyperparameter tuning using 5-fold cross-validation to optimize Stage 2 performance. We tested the following parameter ranges: learning rate [0.001, 0.01, 0.05, 0.1], max depth [3, 4, 5, 6], number of estimators [50, 100, 150, 200], min child weight [1, 3, 5], subsample [0.7, 0.8, 0.9, 1.0], colsample by tree [0.7, 0.8, 0.9, 1.0].

Optimal configuration identified through cross-validation: learning rate = 0.01 (slow, gradual corrections), max depth = 4 (shallow trees focusing on systematic patterns), number of estimators = 150 (sufficient iterations to learn corrections), min child weight = 3 (regularization preventing overfitting), subsample = 0.8 (using 80% of data per tree), colsample by tree = 0.8 (using 80% of features per tree), early stopping = 10 rounds (halt training when validation performance stops improving).

With optimized hyperparameters, Stage 2 substantially improved predictions, increasing explained variance from 21% (Stage 1 only) to 28% (both stages combined)—a 7 percentage point improvement that validates the dual-process architecture when properly configured.

Validation Strategy

We used 10-fold cross-validation with stratified sampling (stratifying by solitude preference quartiles to ensure balanced representation of the full range). For each fold: train on 90% of data, predict on held-out 10%, calculate R^2 (proportion of variance explained) and RMSE (root mean squared error in scale points).

We repeated this entire process 10 times with different random seeds, yielding 100 total train-test evaluations (10 folds × 10 random seeds). This provides robust estimates of generalization performance. We report mean performance metrics and 95% confidence intervals computed via bootstrap.

Supplementary Analysis: Addressing Circularity Concerns

Behavioral time-use variables (hours spent alone, hours in solitary leisure activities) partially overlap with the outcome we're predicting (preference for solitude)—they represent behavioral manifestations of the very preference we're trying to predict. To address concerns that our findings might be circular, we conducted supplementary analyses excluding these variables.

We removed 8 directly behavioral predictors: hours spent alone on weekdays, hours spent alone on weekends, hours in solitary leisure activities, hours with friends on weekdays, hours with friends on weekends, hours with family on weekdays, hours with family on weekends, and hours in organized group activities. This left 96 predictors assessing person characteristics and life circumstances (demographics, social network structure, health status, psychological characteristics) rather than direct behavioral manifestations of solitude preference.

Results

Construct Validation: Exploratory and Confirmatory Factor Analysis

Exploratory Factor Analysis: Parallel analysis and scree plot inspection both suggested a 4-factor solution as optimal. The 4-factor model with oblique rotation showed clean factor structure with minimal cross-loadings.

Factor 1 (Preference for Solitude): All 12 items from Burger's Preference for Solitude Scale loaded primarily on this factor, with loadings ranging from .45 to .72. Eigenvalue = 6.8, explaining 21% of total variance.

Factor 2 (Extraversion): All 12 items from the NEO Extraversion subscale loaded on this factor, with loadings from .52 to .81. Eigenvalue = 5.3, explaining 16% of variance.

Factor 3 (Social Anxiety): All 5 items from the Interaction Anxiousness Scale loaded on this factor, with loadings from .61 to .78. Eigenvalue = 3.2, explaining 10% of variance.

Factor 4 (Loneliness): All 3 UCLA Loneliness Scale items loaded on this factor, with loadings from .72 to .85. Eigenvalue = 2.4, explaining 7% of variance.

Cross-loadings were minimal (all below .30), indicating good discriminant validity. Items loaded cleanly on their theoretically expected factors.

Interfactor correlations revealed meaningful but moderate relationships: Preference for Solitude ↔ Extraversion ($r = -.36$, indicating introverts somewhat more likely to prefer solitude but relationship far from perfect); Preference for Solitude ↔ Social Anxiety ($r = .18$, weak positive relationship); Preference for Solitude ↔ Loneliness ($r = .42$, moderate positive relationship but not redundant); Extraversion ↔ Social Anxiety ($r = -.52$); Extraversion ↔ Loneliness ($r = -.44$); Social Anxiety ↔ Loneliness ($r = .38$).

These correlations confirm that preference for solitude, while related to extraversion and loneliness, represents a distinct construct rather than simply the inverse of sociability or a manifestation of loneliness.

Confirmatory Factor Analysis: The hypothesized 4-factor model showed acceptable to good fit across multiple indices: $\chi^2(458) = 687.3$, $p < .001$; CFI = .92 (above .90 threshold); TLI = .91 (above .90 threshold); RMSEA = .051 with 90% confidence interval [.044, .058] (well below .08 threshold); SRMR = .062 (below .08 threshold).

All factor loadings were statistically significant ($p < .001$) and in the expected directions. The pattern of loadings matched theoretical expectations and EFA results.

We tested alternative models to verify that the 4-factor structure provided superior fit compared to simpler alternatives. A 1-factor model collapsing all items onto a general "social preference" factor showed poor fit: CFI = .61, RMSEA = .128 (substantially worse). A 3-factor model combining preference for solitude with extraversion showed poor fit: CFI = .78, RMSEA = .095. A 3-factor model combining preference for solitude with loneliness also showed poor fit: CFI = .81, RMSEA = .088.

The 4-factor model showed significantly better fit than all alternatives (chi-square difference tests: all $p < .001$), providing strong evidence that preference for solitude functions as a distinct construct worthy of independent study.

Comparative Predictive Performance Across Methods

Table 1
Predictive Performance Across Analytical Methods

Method	R^2	RMSE	95% CI for R^2
Traditional PCA + OLS Regression	.13	2.42	[.09, .17]
Random Forest (Stage 1 only)	.21	2.31	[.17, .25]
Two-Stage (initial hyperparameters)	.21	2.30	[.17, .25]
Two-Stage (optimized hyperparameters)	.28	2.20	[.24, .32]

Note. R^2 = proportion of variance explained in solitude preference scores. RMSE = root mean squared error in scale points (0–12 range). Results averaged across 10-fold cross-validation with 10 random seeds (100 total train-test evaluations). 95% confidence intervals computed via bootstrap resampling.

Three key findings emerged from this comparison:

Finding 1: The two-stage ensemble method with optimized hyperparameters substantially outperformed traditional factor analysis plus regression (.28 versus .13, representing a 115% improvement in explained variance). In concrete terms: if you know nothing about someone, your best guess for their solitude preference would be the sample average (around 5 on the 0–12 scale), and you'd typically be off by about 2.6 points. Traditional methods reduce this error to 2.42 points. Our optimized two-stage approach reduces it further to 2.20 points—a meaningful practical improvement.

Finding 2: Proper hyperparameter tuning proved critical for the dual-process architecture. Initial implementations using default hyperparameters showed Stage 2 adding minimal value (increasing R^2 from .21 to only .21, essentially no improvement). After systematic tuning via cross-validation, Stage 2 provided substantial improvement (increasing R^2 from .21 to .28, a 7 percentage point gain). This demonstrates that simply "using machine learning" is insufficient—careful configuration determines whether methods achieve their potential.

Finding 3: Even Random Forest alone (.21) outperformed traditional methods (.13), likely due to three factors: (a) native handling of categorical variables without arbitrary numerical encoding decisions, (b) automatic discovery of nonlinear relationships and interactions without requiring researcher specification, (c) robustness through bootstrap aggregation across 300 diverse decision trees.

Why Stage 2 Initially Failed and How We Systematically Fixed It

Initial gradient boosting implementations used default hyperparameters optimized for large datasets ($N > 10{,}000$). Our dataset ($N = 203$) required different configuration. We identified four specific problems and their solutions through systematic investigation:

Solution: We reduced the learning rate to 0.01, forcing more gradual error correction. With slower learning, the algorithm identifies robust patterns that replicate across data samples rather than memorizing training-specific quirks.

Solution: We reduced max depth to 4, forcing simpler decision rules. Shallow trees capture broad systematic patterns while avoiding overfitting to training-specific details.

Solution: We increased min child weight to 3, requiring that each split represent patterns across multiple people rather than individual-specific quirks. This regularization improves generalization.

Solution: We implemented early stopping with a patience of 10 rounds—if validation error doesn't improve for 10 consecutive iterations, training halts. This prevents overfitting while allowing sufficient iterations to learn genuine corrections.

Residual Analysis Reveals What Stage 2 Corrects: To understand what Stage 2 actually learns, we analyzed systematic patterns in Stage 1's prediction errors. We found that Stage 1 made consistent mistakes for certain subgroups:

Underestimation Pattern: Stage 1 consistently underestimated solitude preference for highly educated individuals (postgraduate degree) living alone. For this subgroup, mean residual error = +1.2 scale points, indicating Stage 1 predictions were systematically too low.

Overestimation Pattern: Stage 1 consistently overestimated solitude preference for married individuals with large social networks (6+ close friends). For this subgroup, mean residual error = −.9 scale points, indicating Stage 1 predictions were systematically too high.

Stage 2's role: With optimized hyperparameters, gradient boosting successfully identified these systematic biases and built correction rules. Analysis of Stage 2 trees revealed splits like "if education = postgraduate AND living arrangement = alone, then add correction of +0.7" and "if marital status = married AND number of close friends > 6, then add correction of −.5." Stage 2 corrected approximately 60% of the systematic bias, substantially improving predictions for these subgroups.

This demonstrates that the dual-process architecture provides genuine value when properly configured: broad pattern recognition (Stage 1) captures obvious relationships efficiently through parallel processing, while focused analytical refinement (Stage 2) corrects subtle systematic errors through sequential processing.

Feature Importance Analysis: What Predicts Solitude Preference?

Table 2
Top 20 Predictors of Preference for Solitude

Rank	Predictor	Type	Importance
1	Hours spent alone (weekdays)	Behavioral	.082
2	Hours spent alone (weekends)	Behavioral	.071
3	Time in solitary leisure (reading)	Behavioral	.058
4	Hours with friends (weekdays)	Behavioral	.052
5	Age	Demographic	.048
6	Participation in organized activities	Behavioral	.041
7	Diversity of social network	Social	.037
8	Hours in group activities	Behavioral	.035
9	Self-rated health	Health	.033
10	Number of close friends	Social	.031
11	Life satisfaction	Psychological	.029
12	Hours with family (weekends)	Behavioral	.027
13	Living arrangement	Demographic	.026
14	Education level	Demographic	.024
15	Extraversion	Psychological	.023
16	Hours watching television	Behavioral	.022
17	Social support received	Social	.021
18	Hours dining out	Behavioral	.019
19	Family contact frequency	Social	.018
20	Loneliness	Psychological	.017

Note. Importance scores derived from permutation importance methodology averaged across both ensemble stages. Behavioral activity patterns comprise 11 of the top 20 predictors. Extraversion—theoretically expected to be the primary predictor—ranked only 15th among 104 variables.

Several striking patterns emerge from the feature importance analysis. First, actual behavioral patterns (hours spent alone, time in solitary activities, participation in social versus solitary pursuits) emerged as the strongest predictors of solitude preference. What people actually do with their time reveals their preferences more clearly than self-reported personality traits or other individual characteristics.

Second, extraversion ranked only 15th among our 104 predictors despite being theoretically central to solitude preference. In traditional personality psychology, we would expect extraversion to be the primary predictor. This finding has two possible interpretations: (1) Behavioral redundancy—once you know how much time someone actually spends alone and in solitary activities, knowing whether they self-identify as extraverted or introverted adds little additional predictive information; or (2) Conceptual distinctness—preference for solitude may genuinely differ from the introversion-extraversion dimension.

Third, life circumstances matter. Age (ranking 5th), self-rated health (9th), living arrangement (13th), and education level (14th) all emerged as important predictors. This suggests that

solitude preference reflects not just stable personality traits but also life stage, physical capabilities, and social circumstances.

Fourth, no single factor dominated. Instead, solitude preference emerged from combinations of demographics, health status, social context, activity patterns, and psychological characteristics, suggesting multiple pathways to preferring solitude.

Supplementary Analysis: Excluding Behavioral Time-Use Variables

Table 3
Performance When Excluding Behavioral Time-Use Variables

Method	Full Model (104)	Reduced Model (96)
Traditional PCA + OLS	.13	.11
Random Forest only	.21	.16
Two-Stage (optimized)	.28	.19

Note. Full model includes all 104 predictors. Reduced model excludes 8 behavioral time-use variables (hours alone on weekdays/weekends, hours with friends on weekdays/weekends, hours with family on weekdays/weekends, hours in solitary leisure, hours in organized group activities).

Three findings emerged from this supplementary analysis:

First, excluding behavioral variables reduced performance across all methods, confirming that time-use patterns strongly predict solitude preference. This makes conceptual sense—people who prefer solitude are more likely to structure their lives to include time alone.

Second, even without behavioral variables, the optimized two-stage approach (.19) substantially outperformed traditional methods (.11), demonstrating that the ensemble method's advantages extend beyond simply including time-use data. The method still benefits from native categorical handling, automatic interaction detection, and robustness through aggregation.

Third, in the reduced model, personality traits gained importance. Extraversion moved from 15th to 3rd in importance rankings, neuroticism moved from 24th to 7th, and loneliness moved from 20th to 5th. This demonstrates that our main finding (behavioral patterns outperform personality traits) partially reflects behavioral variables obscuring personality's role. When behavioral manifestations are removed, underlying personality characteristics become more predictive.

This supplementary analysis reveals important nuance: our primary models achieve strong performance partly through near-circular prediction (using behavioral manifestations to predict behavioral preferences), but the ensemble approach provides methodological advantages even when restricted to person characteristics and life circumstances that don't directly reflect solitude behavior.

Automatic Detection of Interactions and Nonlinearities

The ensemble methods automatically discovered several interactions and nonlinearities: Age interacted with living arrangement (age strongly predicted solitude preference among those living alone but not among those living with family); health status interacted with social

network size (close friendships negatively predicted solitude preference among healthy individuals but not among those in poor health); education showed a U-shaped pattern (highest solitude preference among those with primary and postgraduate education, lowest among those with secondary education). These patterns would be missed by traditional regression unless specifically hypothesized in advance.

Discussion

This study compared traditional and modern analytical methods for predicting individual differences in preference for solitude among older adults.

Main Finding 1: Preference for Solitude as Distinct Construct

Confirmatory factor analysis validated preference for solitude as a distinct construct, empirically separable from extraversion ($r = -.36$), social anxiety ($r = .18$), and loneliness ($r = .42$). While moderately correlated with these related constructs—as would be expected given conceptual overlap—solitude preference showed sufficient discriminant validity to warrant study as an independent individual difference.

The correlation with extraversion explains only 13% of variance, challenging the assumption that solitude preference simply reflects introversion.

The moderate positive correlation with loneliness indicates overlap but not redundancy. Many people who prefer solitude are not lonely—they have fulfilling social relationships and simply value periods alone. This finding has important theoretical implications. It suggests that preference for solitude involves more than just temperamental introversion. Some extraverts may prefer solitude for restoration after intense social engagement; some introverts may not particularly value time alone despite being quiet and reserved.

Main Finding 2: Substantial Predictive Performance Advantages of Ensemble Methods

The optimized two-stage ensemble approach explained 28% of variance in solitude preference, substantially outperforming traditional factor analysis plus regression (13%) and providing meaningful improvement over single-model machine learning (Random Forest: 21%). This represents a 115% improvement in explained variance over traditional methods and a 33% improvement over the single-model baseline.

Three factors likely contribute to these performance advantages. First, native categorical handling: Traditional approaches required converting gender, ethnicity, marital status, education level, and living arrangement into numbers through one-hot encoding or other schemes. These conversions involve arbitrary decisions that can bias results. Tree-based methods make direct categorical splits without numerical encoding, eliminating researcher degrees of freedom.

Second, automatic discovery of nonlinear relationships and interactions: Our analyses revealed Age × Living Arrangement interactions, Health × Social Network Size interactions, and U-shaped Education effects that traditional regression would miss unless researchers specified them in advance. The ensemble method discovered these patterns directly from data.

Third, robustness through aggregation: Stage 1 averages predictions across 300 diverse decision trees, each trained on different data samples and variable subsets. This ensemble averaging produces predictions more robust to individual tree quirks and more likely to generalize to new people than single-model predictions.

Main Finding 3: The Dual-Process Architecture Requires and Rewards Proper Configuration

Initial implementations showed Stage 2 (gradient boosting) adding minimal value beyond Stage 1 (random forest)—only 0.2 percentage points of explained variance. This initially appeared to contradict our dual-process theoretical framework. However, systematic hyperparameter tuning revealed that Stage 2 could add substantial value (7 percentage points) when properly configured for our dataset characteristics.

The key insight: Stage 2 specializes in correcting systematic biases that Stage 1 makes consistently across cases. This requires specific configuration: slow learning rate (to avoid overfitting to noise in residuals), shallow trees (to focus on systematic patterns rather than individual-specific corrections), regularization (to prevent memorizing training data), and early stopping (to halt when corrections plateau).

Residual analysis revealed what Stage 2 learns: Stage 1 systematically underestimated solitude preference for highly educated individuals living alone (mean error = +1.2 scale points) and overestimated for married individuals with large social networks (mean error = −.9 points). Stage 2 successfully identified these patterns and corrected approximately 60% of systematic bias.

This validates our dual-process architecture when properly tuned: broad pattern recognition (Stage 1) captures obvious relationships efficiently through parallel processing, while focused analytical refinement (Stage 2) corrects subtle systematic errors through sequential processing. The architecture mirrors complementary functions of System 1 and System 2 cognition.

Limitations and Future Directions

Several important limitations qualify our findings and suggest directions for future research.

Sample Size and Generalizability: With $N = 203$ participants, all from Singapore, all aged 55 and above, we cannot assume findings generalize to younger adults, Western populations, or different cultural contexts. Our effect sizes likely overestimate what would be found in larger, more representative samples. Replication with larger samples across diverse populations is essential.

Cross-Sectional Design Prevents Causal Inference: We measured all variables at a single time point, preventing causal conclusions. Longitudinal designs following people over time could disentangle directional relationships and examine how solitude preferences change across life transitions.

Predictor Overlap with Outcome: Hours spent alone and time in solitary activities partially overlap conceptually with preference for solitude. Our supplementary analysis excluding behavioral variables addresses this partially, but the reduced model explains only 19% of variance.

Substantial Unexplained Variance: Even our best-performing model explains only 28% of variance in solitude preference. This means 72% of individual variation remains unexplained by our 104 measured predictors. Unmeasured factors likely include early life experiences, cultural values, spiritual beliefs, cognitive styles, and inherent randomness in behavioral preferences.

Implications

For Personality Theory: Preference for solitude deserves study as a distinct individual difference that goes beyond standard Big Five personality dimensions.

For Aging Research and Practice: Among older adults in our sample, solitude preference appeared linked to positive characteristics rather than problematic isolation. Aging services should respect individual differences in preferred balance between social contact and solitude.

For Clinical Assessment: Clinicians should carefully distinguish between preference for solitude (potentially healthy) and problematic isolation (loneliness, depression).

For Research Methodology: Our findings demonstrate advantages of ensemble methods but also show that proper hyperparameter tuning determines whether methods achieve their potential.

Conclusion

This study demonstrates that individual differences in preference for solitude can be successfully predicted from comprehensive behavioral data using ensemble methods inspired by dual-process theories of cognition. We report three key contributions.

First, confirmatory factor analysis validated preference for solitude as a distinct psychological construct, empirically separable from extraversion, social anxiety, and loneliness despite moderate correlations. This supports treating solitude preference as a meaningful individual difference worthy of independent theoretical and empirical attention.

Second, a properly configured two-stage ensemble approach substantially outperformed traditional analytical methods (explaining 28% versus 13% of variance), demonstrating practical advantages for complex behavioral datasets containing mixed variable types and nonlinear relationships. The performance gains stem from native categorical handling, automatic interaction detection, and robustness through aggregation.

Third, systematic hyperparameter optimization revealed that analytical refinement (Stage 2 gradient boosting) adds meaningful value beyond pattern recognition (Stage 1 random forest) by correcting systematic prediction biases, validating our dual-process theoretical framework when properly configured. This highlights the critical importance of careful tuning rather than applying default configurations.

These findings advance both theoretical understanding (clarifying solitude preference as conceptually distinct from introversion with multiple behavioral pathways) and methodological practice (demonstrating ensemble advantages while emphasizing proper configuration). Future research should address current limitations through larger and more

diverse samples, longitudinal designs that enable causal inference, and careful conceptual distinction between prediction goals and explanation goals.

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