Individual Differences, Multi-Tasking and Learning in Virtual Environments

Connie L. Yuen, University of Alberta, Canada
Patricia M. Boechler, University of Alberta, Canada
Erik A. deJong, University of Alberta, Canada

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Abstract
Virtual environments are inherently social spaces where user productivity and collaborative learning can take place. However, the majority of existing studies to date investigate common behaviours such as multi-tasking within traditional face-to-face learning environments. This study investigated the importance of structuring learning environments to maximize learning and minimize virtual distractions. Using an OpenSim virtual environment, the researchers conducted an experimental study during the Fall 2013 and Winter 2014 terms with 91 undergraduate students at the University of Alberta. The study investigated the influence of participants' prior computer experience and extroversion-introversion on the impact of passive and social distractor tasks during learning and recall of factual information in virtual environments. The results indicated that prior video game use is a significant predictor of lower overall test time and higher overall test score, but the software recognition test, social networking use and virtual world use did not have a significant impact on learning performance. While extroverted individuals tended to complete questions faster under the interactive-type distractor condition, they achieved higher accuracy scores under the passive or no distractor-type conditions. Introverted individuals tended to complete questions faster and more accurately under the no distractor-type condition.

Keywords: multitasking, distractor, computer experience, extroversion, introversion, cognitive style, field independence, field dependence, virtual environment, learning, education, technology

Introduction

Research Problem

With the ever-evolving ubiquitous technologies accessible by many individuals, the desire for immediate communication, multi-sensory stimulation and instant gratification continuously bombard students with a multitude of "wired" interruptions that are filtered and addressed predominantly through multi-tasking (e.g. Carrier, Cheever, Rosen, Benitez, & Chang, 2009, Gazzeley, 2014). As educational philosophies, systems and institutions attempt to keep up with the changing socio-cultural and technological landscape, many educators seek bottom-up approaches to bridge current educational practices and the communicative tools that engage students to learn. Motivating students to focus on the learning task at-hand is particularly challenging for educators because social communication tools are increasingly mobile and consequently encompass a greater capacity for users to simultaneously interact, network and perform other tasks. As more and more educational platforms move online, educators must be cognizant of their students' tendency shift or divide their attention among multiple stimuli. Thus, it is particularly important for educators to structure learning activities or the classroom in a way that maximizes learning and minimizes virtual interruptions.

Previous Studies Addressing the Problem

As students increasingly employ technology-based multi-tasking as an information management strategy (Chun, Golomb, & Turk-Browne, 2011), a growing body of concerned educators and researchers is examining the effects of frequent multimedia task-shifting on student learning, academic performance and overall attentiveness (e.g., Eby, Vivoda, & St. Louis, 2006). Previous literature indicates that there is a mismatch between students' perceived ability to multi-task with digital technologies and the reality that attending to multiple stimuli can significantly impair task performance (Fried, 2008; Grace-Martin & Gay, 2001; Hembrooke & Gay, 2003; Junco & Cotton, 2011; Kraushaar & Novak, 2010). Younger adults are especially prone to multi-tasking because they carry the misconception that multi-tasking with technologies is an easy or efficient approach to handle massive amounts of information (Junco & Cotton, 2011). To date, the majority of studies investigate the multi-tasking behaviours of post-secondary students using technologies and the resulting effects on their learning abilities within face-to-face environments.

Research Questions

This study will investigate two main research questions stemming from human multi-tasking behaviours including whether distractions have an effect on learning within a virtual environment. The first research question addresses computer experience, factual learning and cognitive load. Specifically, research question 1 was divided into two sub-questions: 1A) Can prior computer experience predict learning performance as measured by overall test time in a virtual environment? and 1B) Can prior computer experience predict learning performance as measured by *overall test score* in a virtual environment?

The second research question investigates the personality dimension of extroversion/ introversion on learning performance in the presence of interactive distractors, which are social in nature for this study. Since the data analysis will divide participants into two groups based on the category of extroversion/ introversion, research question 2 is divided into four sub-questions: 2A) Is there a difference for extroverts in time on task given the type of distraction (interactive, passive, none) that is present? 2B) Is there a difference for introverts in time on task given the type of distraction (interactive, passive, none) that is present? 2C) Is there a difference for extroverts in accuracy on task given the type of distraction (interactive, passive, none) that is present? and 2D) Is there a difference for extroverts in accuracy on task given the type of distraction (interactive, passive, none) that is present?

Literature Review

Individual Differences and Personality on Multi-tasking Ability

While most studies of multi-tasking ability agree that digital technologies tend to be distracting and impair learning performance (e.g. Fried, 2008, Junco & Cotton, 2011, Kraushaar & Novak, 2010), few studies have investigated how personality traits and individual factors may impact multi-tasking ability on learning. One recent study by Sanbonmatsu, Strayer, Medeiros-Ward & Watson (2013) found a correlation between participants with high impulsivity and sensation-seeking scores to frequent multi-tasking while driving, however, they caution that these heavy multi-taskers tend to have lower executive control and are thus unable to block out distractions and focus on a single task as compared to light multi-taskers.

Using functional magnetic resonance image (fMRI), Gazzaley (2014) found that multi-tasking correlates with different levels of brain activity in the prefrontal cortex— the main information-filtering centre for the brain— thereby providing some evidence that multi-tasking may affect cognitive load or performance during learning and information processing in the brain. Gazzaley (2014) also speculates that age may be a factor in multi-tasking ability as younger people tend to be faster in switching attention from one task to another, likely because of higher brain plasticity during youth and young adulthood. In addition, today's youth are often digital natives who have grown up with technologies— thereby allowing repeated exposure and practice in multi-tasking with technologies, video games and media.

On the other hand, Stanford Professor Clifford Nass found in multiple studies that those who were heavy media multi-taskers performed poorly compared to light media multi-taskers. Specifically, heavy media multi-taskers were slower to switch from one task to another involving combinations of letters and numbers (Nass, 2010). Nass' studies suggest that there is a tendency for people to be over-confident in one's ability to multitask without negative effects on his or her performance. Similarly, Sanbonmatsu, Strayer, Medeiros-Ward & Watson's (2013) study also found that perceived multi-tasking ability was highly inflated as compared to actual multi-tasking performance. However, there maintained a slight positive correlation among those who self-reported greater multi-tasking ability and actual performance (Sanbonmatsu, Strayer, Medeiros-Ward & Watson, 2013).

Despite these preliminary findings, there is still a wide variability among individual abilities to filter relevant information and multi-task by attending to one task while ignoring others— as such, some researchers suggest that there are common personality factors and differences that correlate with working memory capacity or executive control— which may allow some people to control or attend to various stimuli or tasks better than other individuals (Sanbonmatsu, Strayer, Medeiros-Ward & Watson, 2013).

Virtual Worlds for Education

The embodiment of technologies molds today's society into a world that thrives on the interconnectedness of global media and participatory culture (Jenkins, 2009). In particular, technology-mediated communications has become prominent in altering the way humans develop and understand the world. For instance, emails provide a mode of communication filled with few or ambiguous emotional and non-verbal cues (Smith & Kollock, 2003). Many technologies were developed in attempts to fill the missing elements of face-to-face interactions or simulate the human presence. One such technology involves the immersive experiences offered by virtual worlds or environments. Virtual worlds are generally characterized as simulated three-dimensional (3D) environments that are both immersive and scalable (New Media Consortium and EDUCASE Learning Initiative, 2007). Within these environments, players are typically represented as an avatar that can communicate or interact with the space and other avatars in real-time (New Media Consortium and EDUCASE Learning Initiative, 2007). Virtual worlds should not be mistakenly equated to video games: while the latter occurs within virtual worlds, there is typically an end-goal for the player while virtual worlds are open-ended sandbox environments that do not necessarily have a specific objective. Some widely-popular examples of virtual worlds include Minecraft, MapleStory, IMVU and Second Life (Boechler, 2014).

While a wide variety of virtual environments are available, the most pertinent spaces for investigating educational applications can be found in virtual communities such as OpenSim[1]. Within the education literature there have been some early attempts to utilize virtual environments to teach specific subjects via Second Life [2] for health education (e.g. Angie & Zane, 2011), teacher education, higher-level education (e.g. Serpil, Nurcan, Gamze & Fatih, 2012) and teaching languages. These studies highlight the benefits of utilizing virtual environments in education, citing realistic simulation of events or interactions that can be transferred beyond the virtual environment. These virtual environments simulate real-life scenarios and often closely resemble the user's appearance, communication style and interactions in the real world (e.g. Serpil et al., 2012). Serpil et al. (2012) also found remarkable success in maintaining student engagement with course content and project presentations in the Second Life environment, citing realism, flexibility in formats and self-directed pacing as significant benefits. Therefore, using OpenSim increases the external validity by simulating the real-world applications of virtual environments.

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[1] OpenSimulator: an open source multi-user application server used to create virtual environments (www.opensimulator.org)

[2] Second Life: an online, three-dimensional virtual environment developed by Linden Labs in 2003 in which users interact and navigate the environment as avatars (www.secondlife.com)

Methods

Data Collection

Study Design. This study examined the impact of different types of distractors affecting learning recall within a virtual world. In the first part of the study participants completed the "General Survey"— a combined questionnaire which includes the Computer Experience Questionnaire and the complete Eysenck Personality Questionnaire (Adult version). The General Survey functions as a self-reported personal assessment of (1) familiarity with technology, software, prior computer experience, virtual worlds and social networking between Elementary school age to the present time, as well as (2) personality traits in relation to extroversion-introversion tendencies.

Participants. For the sake of time and efficiency, a convenience sample of 91 participants was recruited from the undergraduate Education program at the University of Alberta from September 2013 to October 2014. Participants received a 5% credit towards an Education course, EDU210: Technology Tools for Teaching and Learning, for voluntary participation in the two-hour combined study or completion of an alternate assignment. The data of two participants were removed from the analysis because the participants did not complete the survey. Therefore, the final sample for analysis was 89 participants, of which 63 were female (71%) and 26 were male (29%). The data collected from participants were anonymized to protect their privacy.

Instruments. To control for the validity and reliability of the experiment, two pre-surveys serve as covariate measures to assist with statistical data analysis.

Computer Experience Questionnaire. The first pre-survey, the Computer Experience Questionnaire (Boechler, Leenaars, & Levner, 2008; see Appendix A), is an instrument that measures computer use throughout elementary, junior high, high school and at present. This survey includes Likert-scale questions intended to account for individual differences and experience with software recognition, video games, social media and virtual learning environments. Students self-report the range of hours spent on each category from not at all to more than 10 hours a week.

Eysenck Personality Questionnaire (Adult version*)*. The Eysenck Personality Questionnaire (Adult version) contains 90 questions measuring three personality temperaments, with 16 questions intended to measure the degree of extroversion-introversion on a scale of 1-16, with scores of 0-8 being indicative of introverted tendencies and 9-16 as having more extroverted tendencies. In accordance with the Eysenck Personality Questionnaire analysis procedures, only 16 out of the 90 questions were considered in calculating the final score for extroversion-introversion— the remaining questions acted as fillers in order to reduce the likelihood that participants would predict the intent of the survey and answer according to demand characteristics. While the results could be interpreted as scores across a continuum, using dichotomous categorizations of extroversion/introversion allows for a greater interpretation of its impact on the test score and time. According to Eysenck Personality Questionnaire Manual (Eysenck & Eysenck, 1964), scores can be categorized such that a score of "1" would indicate low extroversion levels, which could be interpreted as being "introverted", while a score of "14" would be considered high on the continuum of extroversion. A mid-score represents an intermediate level of extroversion. This interpretation approach allows for a more accurate reflection of personality traits within the sample. In order to allow for easy comparisons between extroverted and introverted participants, the categorical approach was used.

Procedures. For this quantitative study, an experimental design was used to "test [the] impact of treatment or intervention on [the] outcome" (Creswell, 2009, p. 145-146). To carry out the quantitative experiment, a within-subject design was utilized to control for variations among individual learning and assessment performance or speed. As such, the experiment included control variables and each participant encountered one of three randomly-ordered conditions – that is, distractor type – during the learning phase in virtual environment task. The first step involved recruiting 89 undergraduate students from the Educational Psychology research participant pool at the University of Alberta. These students received course credit for participating in the 1-hour session in a large classroom setting accommodating up to 20 students at a time. All participants were required to sign a consent form before the researcher gave specific instructions for each task.

The first task was to complete the General Survey which measures prior computer experience (Computer Experience Questionnaire) and degree of extroversion-introversion (Eysenck Personality Questionnaire). Following the pre-surveys, participants were instructed how to navigate in the virtual environment using the keyboard arrows and follow the coloured arrows along a pathway. They were also tasked with reading all the windows or any instructions on the billboards they encounter. Participants were also informed that the virtual environment task had two phases and they would need to complete both to the best of their ability. These virtual tasks were, in fact, divided into a learning phase and testing phase. During the learning phase, participants navigated as an avatar along a directed pathway and read a billboard passage about the history of the London Tube Stations-- a fairly uncommon topic to prevent prior knowledge from becoming a confounded variable.

Experimental conditions. While reading each of these passages, one of three conditions randomly appeared: an interactive chat distractor, a passive text distractor or no distractors. Each participant experienced all three conditions exactly four times in random order. The *interactive distractor* is defined as a secondary, unrelated task that appears in a new window during the main learning task and prompts the participant to selectively attend to, process and input a response accordingly. Four different interactive distractors were used in the study that questioned, in random order, the following: What is your major area of studies? What year of studies are you currently in? What is the last class you went to? Have you eaten lunch yet? (see Appendix G for example of an interactive distractor used in the virtual world).

The *passive distractor* is defined as a secondary, unrelated task that appears in a new window during the main learning task but only prompts the participant to selectively attend to the stimulus without inputting any response. Four different passive distractors were used in the study that displayed the following conversational statements in random order: I'm majoring in Biology; I'm currently in my third year of studies; I just finished History class; and I just had lunch in the cafeteria (see Appendix G for example of a passive distractor used in the virtual world). Both the interactive and passive distractors were written in a conversational tone in order to make the distractors more authentic to external distractors found in real-life and virtual settings; this is in contrast to other distractor studies (e.g. Nass, 2010) that utilize math, image identification or vocabulary questions, for example, as a distractor.

The control condition in the study, *no distractor*, means that participants did not encounter a distractor while reading a billboard. This condition was also randomly selected during each session. Participants will be drawn from a convenience sample of undergraduate students enrolled in Education courses at the University of Alberta. For each participant, the distractor type was recorded alongside each randomly-matched billboard in order to properly assess the mean scores for factual learning recall as influenced by each distractor type.

Learning task. Note that participants were not primed to learn the information for testing specifically but to simply read the billboards in order to reduce the impact of test-wiseness and demand-characteristics (See Baddeley, 1997; Hulstijn, 1989). During the testing phase, participants completed a multiple-choice test displayed on the final billboard to assess factual learning recall of the information previously presented. The OpenSim virtual environment allowed for time-tracking throughout each phase, including the specific time taken to navigate or walk within the virtual environment, reading time for each billboard and completion time for the test questions. Participants' learning performance on factual learning recall was assessed by analyzing the overall score out of 12 and total time taken to complete the multiple-choice test.

Enhancing validity and reliability. In an effort to enhance the internal validity of the experiment, the researcher purposefully excluded the use of a pre-test of the test topic about the history of the London Tube Stations in order to reduce potential threats caused by repeated testing. By doing so, the researcher can be more confident in the results since participants will not become more familiar with the outcome measure or potentially remember responses for the post-test.

Results

Definition of Terms for Analysis

To begin, the following terms must be clarified. The "overall test time" refers to the time in minutes taken to complete the 12-item multiple choice test during the virtual world testing phase (phase two) of the study. Here, participants demonstrated their factual recall ability of the billboard information presented during the learning phase (phase one). The "overall test score" refers to the number of correct responses in the 12-item multiple choice test, with 1 score awarded for each correct response up to a maximum of 12 and no score added for incorrect or missing responses. For research question 2, "time on task" refers to the time taken to complete four multiple choice test questions based on the three types of distractors (interactive, passive or none) presented while participants read billboards during the learning phase. Similarly, "accuracy on task" refers to the number of correct responses up to a maximum of 4 multiple choice test questions based on these three types of distractors.

Research question 1. The first question examines whether prior computer experience predicts learning performance as measured by (A) overall test time, and (B) overall test score, in a virtual environment. Since research question 1A seeks to understand if prior computer experience predicts learning performance as measured by overall test time in a virtual environment, a multiple regression analysis was used. The independent variables include the components used in the Computer Experience Questionnaire including the software recognition test, total video game use, total social networking use and total virtual world use; the dependent variable is the overall test time for recalling information from the billboards, which is a continuous variable. Based on the hierarchal multiple regression analysis results, Total Video Game Use significantly predicted MC_test_time, $F(3, 85) = 5.419$, $p < .0005$. The Adjusted R Square is 0.131 or 13.1%, which suggests a small effect size.

Research question 2. For the second research question, the sample group was further divided into a category of extroverts and introverts based on the scores obtained from the Eynseck Personality Questionnaire in order to determine if there were test time or test score differences for either group based on distractor types. As the sample was drawn from undergraduate education students on a voluntary basis without specific requirements, an uneven distribution of extroverts and introverts were already present (n= 64 and n=25, respectively). As such, this sample was an authentic reflection of the undergraduate education student population, which can be used to draw further implications for research in this specific context.

According to the results discovered in research questions 2A and 2B, introverted participants took slightly more time to answer questions in the presence of interactive distractors (*M* = 4.718, *SD* = 0.182) and no distractors (*M* = 3.109, *SD* = 0.176), but took relatively less time in the presence of passive distractors (*M* = 4.054, *SD* = 0.213) than the extroverted participants (Interactive: *M* = 3.600, *SD* = 0.117; None: *M* = 3.093, *SD* = 0.113 and Passive: *M* = 4.309, *SD* = 0.137, respectively). For extroverts (question 2C), accuracy on task for distractor type was highest for passive distractor (*M* = 3.22 ± *SD* = 0.888 score), moderate for the control condition with no distractors (*M* = 2.683± *SD* = 0.997 score) and lowest for the interactive distractors (*M* = 2.32± *SD* = 1.060 score). For question 2D, the ANOVA revealed that for introverts, accuracy on task for distractor type was highest for the control condition of no distractors (*M* = 3.72 ± *SD* = 0.737 score), moderate for passive distractors (*M* = 3.280± *SD* = 0.178 score) and lowest for the interactive distractors (*M* = 2.440± *SD* = 0.259 score).

Discussion of Results

For research question 1, it was found that only video game use was a significant predictor of overall test time and test score. That is, more prior experience with video games predicts lower overall test time and higher test scores. Interestingly, the time in which prior video game experience was acquired did not affect overall time or accuracy. A probable explanation for this result is that video games require players to attend to multiple stimuli and task-shift quickly. For example, the game interface may have multiple gauges for health points, magic points, score, inventory, etc. displayed while players are engaging in interactive events during gameplay. Therefore, the repeated practice and exposure within video games likely decreased cognitive load for similar onscreen activities such as playing in a virtual environment. Also, since video games are often set in virtual environments, they may have already acquired skill sets that allow them to quickly skim material and recognize cues that aid information recall. As exposure and experience in video games is accumulated over time, the specific time period in which this experience occurred would be irrelevant. Software recognition and social networking use may not have had a significant effect because the skills required in these activities would be less relevant to the virtual environment tasks at-hand. For instance, the virtual world did not analyze the accuracy of social responses or require recognition of other types of software such as SPSS.

For research question 2, extroverts tended to take the most time to complete the test during the presence of passive distractors instead of interactive distractors. This result may reflect arousal theory in that extroverts may require more stimulation and have a higher threshold for social activity; thus the researcher speculates that there is an optimal level of arousal that benefits extroverted individuals when they learn in the presence of interactive distractors that are socially-oriented. In addition, extroverts may be more adept at managing social interactions while multi-tasking and may require less time formulating a response because of their predisposition to value social interactions over factual learning required for the test. Thus, the extroverts may have rushed through the test or were less concerned about the test performance. Also note that extroverts actually obtained the worst test scores for interactive distractors. This may indicate that while extroverts may be quick to complete the test, they did not process the primary task as effectively when information was presented in the presence of interactive distractors. Thus, while experience or comfort with social situations may predict faster response times, accuracy scores may decrease as the reduced time needed may require greater processing or mental exertion. Consequentially, less cognitive processing is allocated to the primary task.

On the other hand, introverts tended to take the most time to complete the test and had the lowest test scores during the presence of interactive distractors. In line with the arousal theory, introverts have a lower optimal level of arousal, which interactive distractors will likely overshoot. As a result, introverts perform relatively poorly in response to too much arousal. In addition, introverted participants may be more easily distracted by interactive messages or utilize more attentional resources to process interactive distractors because of less experience or greater discomfort in social situations. Furthermore, the extra time used for responding to the test questions may have been a reflection of more careful concentration or focus on the primary task.

Assumptions and Limitations

Some assumptions of this true experimental design include the internal validity of test scores and completion times as indicators of the quality of factual learning, as well as the fact that participants are moderately motivated to learn within the virtual environment to obtain course credit or to experience alternate delivery formats in education. The study did not account for test-wiseness or familiarity with the test topic. Furthermore, while the study examined three levels of distractors, distractions can come in many forms and contexts. For example, this study only investigated visual, social distractors. Future studies could examine distractors involving audio or kinaesthetic elements. These unexamined distractor types may reflect real-life situations an individual may encounter in cases such as receiving a video call, playing music while working on a task or being alerted to a message through the vibration of a phone. Other avenues for future exploration could address the hypothesis that learners may exert less cognitive effort when switching between tasks while using the same device or one computer in comparison to switching between various devices. In this case, the proximity or immediacy of the distractions may have an effect on the participant's performance when learning within the virtual environment. Another limitation of the study is that the results may not apply to other populations such as children, adults not in post-secondary education. Future research into different populations and fields may be required.

Conclusion

Based on the results of this study, video game experience may aid multi-tasking performance through familiarity of simultaneously attending to various stimuli on the computer screen. In addition, since video games take place in virtual environments, the transfer of skills and comfort with these platforms may translate to better performance on factual learning recall during distractions. However, more generalized experience with computers such as software recognition or familiarity with social media does not seem to have such an impact— perhaps because they train a different set of skills on a different platform.

Personality traits also seem to have some predictive value for the ability to effectively multi-task and recall factual information during a test. Specifically, extroversion may predict faster test times but lower accuracy scores compared to introverts due to the predisposition to value social or interactive tasks over factual applications. Overall, while preliminary research in virtual learning environments has demonstrated that some personal factors may affect the impact of multi-tasking on factual learning, there is still much to undercover about the effect of distractors on various learning tasks and diverse populations. These insights may enhance one's understanding of learning in the technological, multi-tasking world.

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