Associations Between Pitch (F0) and Language Competence of Four-Year-Old German Children

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Abstract

Characteristics of children's voice such as pitch may indirectly reflect some sociodemographic or medical characteristics of children or their families. To our knowledge, no studies exist on a possible link between pitch and language competence. We analysed this link for German four-year-old children. A sample of 496 kindergarten children was tested with the validated language screening "Kindersprachscreening" (KiSS.2): speech comprehension, vocabulary, articulation, grammar, and phonological short-term memory (repetition of non-words and sentences). The latter subtest was utilized for the measurement of children's pitch (F0). The mean pitch was correlated with KiSS.2 results and sociodemographic characteristics of children and their families that were documented in KiSS.2 questionnaires for parents and kindergarten teachers. Higher pitch was associated with parents' lower educational level (low but significant correlations). No associations between pitch and KiSS.2 results were found but kindergarten teachers described children with a higher pitch as having more limited German language competence. Successive bilinguals had a somewhat higher pitch than simultaneous bilinguals and were much more often classified in KiSS.2 as needing medical assistance in acquiring German (24.5% vs. 10.7%). No direct associations were found between children's pitch and German language skills according to KiSS.2. However, children with a higher pitch were more often successive than simultaneous bilinguals and, thus, more often migrants. The socioeconomic status of their families was lower and respective children needed more often medical assistance in acquiring German. Lower body weight of children with a lower socioeconomic status is a well-known finding and probably results in their higher pitch.

Keywords: language assessment, language acquisition, voice, pitch, German language

Introduction

Pitch is the perceived highness or lowness of a sound, determined by the fundamental frequency (F0, the rate at which vocal folds vibrate, measured in Hertz, Hz). Usually, adult males have pitch values between 75 and 300 Hz, adult females between 100 and 500 Hz, children (including babies) between 150 and 600 Hz.

Pitch is associated with or depends on age (Eichhorn et al., 2008), biological sex (Niebuhr, 2015; Pépiot, 2014), language (Järvinen et al., 2012; Mennen et al., 2012; Pépiot, 2014), region, among speakers of one language (Weirich et al., 2024), communication context (e.g., conscious manipulation of F0 to convey personality traits and leadership status; Signorello et al., 2020). For instance, children and women have a higher pitch than adults and men respectively, representatives of the upper class show larger modulations of pitch in French than representatives of lower classes (Pépiot, 2024).

There are no direct links between pitch and speech-language impairments (Alcock et al., 2000), apart from very special cases such as apraxia of speech (Wong et al., 2021). Also, no studies were found on possible associations between pitch and children's language competence. However, it can be assumed that due to associations between pitch and some sociodemographic characteristics, pitch can be linked, at least vaguely, to advanced or limited language skills. Among other things, since children of parents with a low educational level often have limited language skills, even in their first language (Gambaro et al., 2019; RuhrFutur gGmbH & Regionalverband Ruhr, 2024), and since people with different educational levels in some countries have different pitches, there can be an indirect association between parents' (or children's) pitch and children's language competence.

In the current study, associations between pitch and (a) German language competence, (b) sociodemographic characteristics of German children and their families were analysed. It was assumed that pitch could reflect children's sociodemographic characteristics and that these characteristics could also influence German language skills. Results of four-year-old children were compared to those of (a much smaller sample of) five-year-old children.

Methods

Four-Year-Old Children

Data collected in a study on the development of two language tests were re-analysed retrospectively. A sample of 496 German kindergarten children (age 4; 0–4; 11 years, $M = 53.5$ months; 243/49.0% boys, 253/51.0% girls) was utilized. Out of 496 children, 192 were monolingual Germans (38.7%) and 304 bi-/multilinguals (61.3%), with largest subgroups speaking Turkish, Arabic, and Russian. There were no special inclusion criteria in the original prospective study, except age (four years) and a written consent signed by parents.

All children were tested in German kindergartens with the validated, standardized language screening "Kindersprachscreening" in the second version ("Language screening for children"; KiSS.2, Holler-Zittlau et al., 2011). This test contains (a) subtests on the speech comprehension, vocabulary, articulation, grammar, and phonological short-term memory (repetition of non-words and sentences), (b) questionnaires for parents and kindergarten teachers to assess sociodemographic and medical characteristics of children and their families. KiSS.2 results can be dichotomized in "pass/fail", with "pass" meaning age-appropriate

German language skills and "fail" meaning need of additional educational and/or medical assistance in the German language acquisition. Usually children who need medical assistance (that is, children with some language(-related) impairments and disorders) also need educational assistance (that is, German language courses).

Also, all children were tested with the so called "quasi-universal" non-words (QUNW) by Chiat (2015): *Zibu*, *Lita*, *Maki*, *Luni*, *Sipula*, *Bamudi*, *Malitu*, *Lumika*, *Zipalita*, *Mukitala*, *Kasulumi*, *Litisaku*, *Sipumakila*, *Tulikasumu*, *Malusikuba*, and *Litapimuti*. Although KiSS.2 also contains non-words for the assessment of the phonological short-term memory, there is a large difference between items used in KiSS.2 and in QUNW. Non-words in KiSS.2 are German-based and, therefore, children with limited German language skills are clearly disadvantaged. KiSS.2 non-words assess not only memory, but also German vocabulary and grammar (morphology) skills as well as German phonotactics. These linguistic interferences make the interpretation of results more difficult. QUNW are not German-based or, to be more precise, they are based on all languages of the world. In the development of QUNW, language-specific characteristics such as consonant clusters were avoided. Therefore, German language skills do not help children in the repetition of QUNW. It is highly likely that QUNW have a more direct access to the phonological short-term memory than language-specific non-words such as those in KiSS.2.

Pitch (F0) was calculated on the basis of repetition tasks:

- Non-words:
  - KiSS.2 non-words: *Gune, Meling, Flome, Triser, Schabu, Feilister, Posalin*,
  - QUNW: *Zibu, Lita, Maki, Luni, Sipula, Malitu*,
- KiSS.2 sentences: *Die Enten fressen am See "*The ducks are eating by the lake", *Das Telefon klingelt den ganzen Morgen* "The phone is ringing all morning", *Max kauft ein Eis* "Max is buying an ice-cream".

Analysis of pitch was carried out in the software "Praat" (Paul Boersma and David Weenink, Faculty of Humanities, University of Amsterdam, The Netherlands). Mean F0 values of 16 items described above were used in statistical calculations.

Calculations on associations between pitch (F0) and (a) KiSS.2 results (German language competence), (b) KiSS.2 questionnaire items (sociodemographic and medical characteristics of children and their families) were carried out by the following statistical methods:

- Spearman's correlations for metrical and ordinal variables,
- Mann-Whitney *U* tests for dichotomous vs. metrical or ordinal variables,
- linear-by-linear associations (lbl): dichotomous vs. ordinal variables,
- Kruskal-Wallis *H* tests for categorical vs. metrical variables (this test does not appear in the Results section because its results were not statistically significant).

Also, Friedman test was utilized to analyse the stability of pitch. This test was applied separately for the repetition of KiSS.2 non-words, KiSS.2 sentences, and QUNW. It answers the question whether children change their pitch significantly within these three tasks.

Five-Year-Old Children

Results of four-year-old children were compared to those of five-year-olds from the same (originally prospective) study on the development of two language tests. The sample of five-year-old children was much smaller than the sample of four-year-olds (N = 306; 174/56.9%

boys, 132/43.1% girls; age 5; 0–5; 11 years, *M* = 64.2 months; 69/22.5% monolingual Germans, 237/77.5% bi-/multilinguals). Largest subgroups of bi-/multilinguals spoke Turkish, Arabic, and Russian at home. Four- and five-year-old children were tested together with the same language tests in the same regions and at the same time, with the same inclusion criteria (age, informed consent signed by parents). All statistical calculations described above were repeated for five-year-olds.

Results

Four-Year-Old Children

Descriptive statistics on pitch (F0) can be found in Table 1.

Table 1
Descriptive Statistics on Pitch (F0), Measured in Hertz: Four-Year-Old Children

Pitch	KiSS.2 non-words	QUNW	KiSS.2 sentences	Total
Mean ±SD	274.7 ±33.5	284.4 ±37.8	277.9 ±33.0	279.2 ±31.4
Minimum	179	193	185	186
Maximum	423	563	453	377

Note. QUNW "quasi-universal" non-words, SD standard deviation

For more details, see Appendix (Tables A1, A2). It demonstrates a considerable variation in the results. For instance, the mean pitch value of the item *Meling* was *M* = 269.7, whereas the mean value of *Zibu M* = 292.9.

Table 2 shows correlations between pitch values (Hz) in all three repetition tasks. All correlations can be considered high.

Table 2
Associations Between Pitch (F0) in Repetition Tasks (Four-Year-Old Children)

Repetition tasks	ρ
KiSS.2 non-words vs. "quasi-universal" non-words	.828
KiSS.2 non-words vs. KiSS.2 sentences	.728
"Quasi-universal" non-words vs. KiSS.2 sentences	.716

Note. Spearman's Correlations (all ps < .001)

There were no statistically significant correlations between pitch (mean of all three repetition tasks) and children's German language skills according to KiSS.2 (Table 3). However, children with a higher pitch showed a weaker performance in the phonological short-term memory (both German-based and language-independent non-words). Thus, lower pitch was associated with the better phonological short-term memory. For more detailed results, see Table A3 in the Appendix.

Table 3

Associations Between Pitch (F0) and Total Scores of Correct Answers in Language Tests (Four-Year-Old Children)

Language tests	ρ
KiSS.2: speech comprehension	-.060
KiSS.2: vocabulary	.015
KiSS.2: articulation	-.074
KiSS.2: grammar	-.013
KiSS.2: repetition of non-words	-.113**
KiSS.2: repetition of sentences	-.085
KiSS.2: total score	-.057
"Quasi-universal" non-words	-.140**

Note. *** $p < .001$, ** $p < .01$, * $p < .05$; Spearman's correlations

There were also no differences in pitch between children needing or not needing additional educational and/or medical help in acquiring German, and, thus, in the result "pass/fail" in KiSS.2. However, children's German language competence was assessed not only objectively (by KiSS.2), but also subjectively: kindergarten teachers were asked to estimate it by school grades (from 1 "excellent" to 6 "insufficient"). This estimation was documented in KiSS.2 questionnaires for kindergarten teachers and was not based on KiSS.2 (language screening) results. Here, children with a higher pitch received more often unfavourable estimations of their German language skills: $\rho = .102$, $p = .013$. Thus, kindergarten teachers tended to believe that children with a higher pitch had a somewhat weaker German language competence. However, in other questionnaire items kindergarten teachers did not notice any differences between children with a higher and lower pitch. The following questionnaire items did not deliver statistically significant results:

- "How would you estimate German language skills of the child at the time point when he/she began to attend this kindergarten?",
- "The child understands complex instructions",
- "Everybody can understand the child",
- "Child's vocabulary appears age-appropriate",
- "Child's pronunciation appears age-appropriate",
- "The child can speak in full sentences",
- "The child can use articles (*der*, *die*, *das*) correctly",
- "The child speaks German age-appropriately".

In other words, kindergarten teachers believed that children with a higher pitch had weaker German language skills (estimated by school grades) but could not explain which linguistic domains they mean. Also, when estimated on the scale from 1 "never" to 5 "always", children with higher and lower pitches did not differ in German language skills according to kindergarten teachers (item "The child speaks German age-appropriately").

Regarding associations between pitch and sociodemographic as well as medical characteristics of children and their families, there were almost no statistically significant results. Even such well known-factors as biological sex and age (here: 4; 0–4; 5 vs. 4; 6–4; 11 years and age in months) did not yield significant results. Other factors were:

- parents' German language skills (subjective estimation),
- parents' first languages (German vs. not German),
- age when parents began to learn/acquire German,
- age when the child began to acquire German,
- "How often does the child play with other children who speak the same non-German language?",
- "The child likes to play with other children",
- "The child speaks out when playing with other children",
- "The child plays with German-speaking children" (two items: "in the kindergarten" and "beyond"),
- "The child has been attending this kindergarten for … months",
- "Does the child attend the kindergarten for half a day or a full day?",
- "Does the child attend associations or study groups?",
- "Did the child attend a nursery school in the first two years of life?",
- "Does the child participate in a German language course?",
- "Does the child have any language-related disorder or impairment?",
- "Does or did the child undergo a speech-language therapy?",
- "Does or did the child undergo a therapy not related to language?",
- "Does the child speak his/her mother tongue age-appropriately [if not German]?",
- "Did relatives express concerns about the child's language development?",
- "Did the child begin to speak his/her first language very late (first words after the second birthday or later)?",
- "Does the child have to take medicine regularly?",
- "Did the child have any head injuries or surgeries?",
- "Does the child often have otitis media?",
- "The child does not hear well",
- "Does the child have a motor disorder?",
- "Does the child stutter?",
- "Did the child have a risk or early birth (weight < 1500 gr or birth before the 28th gestation week)?",
- "Does the child attend pediatricians more frequently than other children?",
- "Does the child have any relatives…
- with dyslexia (problems with reading and writing)?",
- with a language disorder/impairment?",
- who had to undergo a speech-language therapy?",
- who began late to speak (first words after the second birthday or later)?",
- who stutter?",
- languages spoken at home,
- "How often is German spoken at home?",
- monolingual Germans vs. bi-/multilingual children,
- monolingual vs. bilingual vs. trilingual children,
- immigrants vs. non-immigrants,
- subgroups of bi-/multilingual children: Turkish-, Russian-, Arabic-speaking etc.

However, there was a marginally significant association between pitch and successive (n = 424) vs. simultaneous (n = 391) bilingualism: Z = -1.90, p = .057. Successive bilinguals were defined as those acquiring the second language from the second year of life or later. Simultaneous bilinguals were those who acquired both languages since birth. Successive bilinguals had a higher pitch than simultaneous ones: M = 281.0 ±29.7 vs. 276.1 ±33.2. In this context, it is important to know that usually successive bilinguals have weaker German language skills than simultaneous ones. For instance, in the present sample they needed more often medical assistance in acquiring German ($\chi^2_{(1)}$ = 26.29, p < .001; 104/424 (24.5%) vs. 42/391 (10.7%)). Apart from the later age of the German language acquisition, they acquired German under several unfavourable sociodemographic conditions: more often…

- non-attendance of nursery schools: $\chi^2_{(1)}$ = 11.47, p = .001,
- non-attendance of associations and study groups: $\chi^2_{(1)}$ = 5.89, p = .016,
- other languages than German spoken at home: lbl = 95.48, p < .001,
- playing with children speaking the same non-German language(s) as the child in the kindergarten group: *lbl* = 4.88, p = .027,
- not playing with German-speaking children in the kindergarten: *lbl* = 16.61, p < .001,
- lower mothers' educational level: *lbl* = 10.86, p = .001,
- limited German language skills of mothers (*lbl* = 37.89, p < .001) and fathers (*lbl* = 20.54, p < .001), as self-estimation,
- immigrant background (definition: either the child or at least one of his/her parents migrated to Germany): $\chi^2_{(1)}$ = 14.90, p < .001.

No counter-examples were found, that is, conditions that were favourable for successive bilinguals and unfavourable for simultaneous ones. There were no differences in age and biological sex between successive and simultaneous bilinguals.

Also, children with a higher pitch had mothers (ρ = -.101, p = .034) and fathers (ρ = -.120, p = .013) with a lower educational level. In this context, it should be mentioned that parents' low educational level was associated with numerous factors that can be considered unfavourable for the German language acquisition (Table 4). Most of them refer directly or indirectly to the reduced quality and/or quantity of the German language input.

Table 4

Associations Between Parents' Low Educational Level and Unfavourable Sociodemographic/Medical Characteristics of Four-Year-Old Children and Their Families

Questionnaire items	Method	Mother	Father
attendance of kindergartens for half a day (and not a full day)	lbl	18.27***	7.05**
non-attendance of nursery schools	lbl	38.27***	10.85**
non-attendance of associations and study groups	lbl	21.08***	6.34*
less often German spoken at home by mothers	lbl	4.56*	n.s.
the same for fathers	lbl	10.00**	n.s.
the same for the child	lbl	4.33*	n.s.
presence of other children speaking the same non-German first language in the kindergarten group	lbl	5.23*	n.s.
playing with this child/these children	ρ	.183*	n.s.
not speaking out when playing with other children	ρ	.181***	.159**
therapies (excluding speech-language therapies)	lbl	5.66*	n.s.
"The child needs to attend paediatricians more often than other children"	lbl	7.01**	n.s.

a motor disorder	lbl	11.29**	5.37*
cases of dyslexia in the family	lbl	10.94**	10.29**
cases of language disorders/impairments in the family	lbl	4.74*	n.s.
cases of late language onset in the family	lbl	9.45**	n.s.
not German as mother's first language	lbl	7.51**	n.s.
not German as father's first language	lbl	12.10**	10.22**
later age of the German language acquisition by the child	ρ	-.190***	-.111*
the same for the father	ρ	-.164**	-.114*
worse mother's German language skills	ρ	.152**	n.s.
the same for the father	ρ	.179***	.246***
hearing problems of the child	ρ	-.107*	n.s.

Note. *** $p < .001$, ** $p < .01$, * $p < .05$, n.s. not significant; linear-by-linear associations (lbl), Spearman's correlations (ρ)

No counter-examples were found, that is, conditions that were favourable for children whose parents had a lower educational level and unfavourable for children whose parents had a higher educational level. Parents' educational level was not associated with children's biological sex or age (as possible confounding variables that can influence pitch).

Finally, bi-/multilinguals who had peers speaking the same non-German language in the kindergarten group used significantly lower pitch than those who did not have such peers (Z = -2.03, p = .043, M = 275.6 ±29.3 vs. 282.1 ±32.7). There were no differences in age and biological sex between children having and not having such peers.

All calculations above were carried out for all children taken together. Since it could not be excluded that associations between pitch and German language skills would deliver very different results for monolingual Germans and bi-/multilinguals, calculations on associations between pitch and KiSS.2 as well as QUNW were repeated separately for these subgroups.

For monolingual German children, there was only one significant correlation between pitch and language tests: children who scored higher in QUNW had a slightly lower pitch (ρ = -.144, p = .046). Also, there were no associations between pitch and dichotomized KiSS.2 results or subjective estimations of German language skills by kindergarten teachers. Bi-/multilingual children showed more significant findings. Children who scored higher in KiSS.2 non-words (ρ = -.157, p = .006), KiSS.2 sentences (ρ = -.153, p = .008), KiSS.2 total score (ρ = -.115, p = .047), and QUNW (ρ = -.125, p = .030) had a lower pitch. Also, children who were classified in KiSS.2 as needing additional medical assistance in acquiring German had a marginally significantly higher pitch: Z = -1.89, p = .063; M = 287.1 ±29.5 vs. 277.8 ±32.0). It can be concluded that differences in pitch occurred predominantly in the subgroup of bi-/multilinguals. Therefore, calculations on associations between pitch and sociodemographic or medical characteristics of children and their families were repeated for this subgroup.

Again, German language skills of children with a higher pitch received worse estimations by kindergarten teachers (ρ = .141, p = .018). However, kindergarten teachers did not notice any differences between children with a higher and lower pitch in separate linguistic domains. Also, children with a higher pitch had marginally significantly more often cases of undergoing speech-language therapies in the family (Z = -1.82, p = .069; M = 290.4 ±30.0 vs. 278.0 ±32.4). Arabic-speaking children had marginally significantly lower pitches than other bi-/multilinguals (Z = -1.73, p = .084; M = 272.8 ±28.2 vs. 280.0 ±32.4). Bi-/multilinguals who had peers speaking the same non-German language in the kindergarten group, used marginally

significantly lower pitch (Z = -1.77, p = .076, M = 275.7 ±29.7 vs. 283.3 ±33.9). There were no differences in age and biological sex between (a) children with and without cases of speech-language therapies in the family, (b) Arabic-speaking and other children, (c) children with and without peers who speak the same non-German language in the kindergarten group. No other significant or marginally significant results were found. However, sample sizes were often too low for Mann-Whitney U tests in the subgroup of bi-/multilinguals.

Friedman test showed that children (the whole sample of four-year-olds again) changed pitch within subtests, that is, pitch was not stable. It was valid for KiSS.2 non-words ($\chi^2_{(6)}$ = 57.69, p < .001), KiSS.2 sentences ($\chi^2_{(2)}$ = 34.94, p < .001), and QUNW ($\chi^2_{(5)}$ = 112.80, p < .001).

Five-Year-Old Children

Descriptive statistics on pitch can be found in Table 5. For more details, see Appendix (Tables A4, A5). Five-year-old children used, on average, a lower pitch than four-year-old ones: in KiSS.2 non-words (Z = -3.90, p < .001), in KiSS.2 sentences (Z = -2.88, p = .004), in QUNW (Z = -4.91, p < .001), and in all tasks taken together (Z = -4.35, p < .001).

Table 5
Descriptive Statistics on Pitch (F0), Measured in Hertz: Five-Year-Old Children

Pitch	KiSS.2 non-words	QUNW	KiSS.2 sentences	Total
Mean ±SD	266.7 ±32.6	272.5 ±33.8	272.7 ±34.4	270.7 ±31.3
Minimum	198	202	194	204
Maximum	471	460	461	464

Note. QUNW "quasi-universal" non-words, SD standard deviation

Table 6 shows correlations between pitch values (Hz) in all three repetition tasks. All correlations can be considered high.

Table 6
Associations Between Pitch (F0) in Repetition Tasks (Five-Year-Old Children)

Repetition tasks	ρ
KiSS.2 non-words vs. "quasi-universal" non-words	.833
KiSS.2 non-words vs. KiSS.2 sentences	.744
"Quasi-universal" non-words vs. KiSS.2 sentences	.705

Note. Spearman's Correlations (all ps < .001)

There were no associations between mean pitch (F0) and dichotomized or metrical KiSS.2 results as well as QUNW and subjective estimations of German language skills by kindergarten teachers. This is valid not only for the whole sample but also for the subgroups: monolingual Germans and bi-/multilinguals. For details on correlations between language tests and pitch, see Table A6 in the Appendix.

However, several associations between pitch and sociodemographic characteristics of children were found (in the whole sample of five-year-olds). Children with a higher pitch…

- were younger (in months): ρ = -.142, p = .013 (if we take subgroups 5;0-5;5 vs. 5;6-5;11 years, then the difference was marginally significant: Z = -1.96, p = .050),
- were more often monolingual Germans than bi-/multilinguals: Z = -2.28, p = .023 (it

should be considered that monolingual Germans were significantly younger than bi-/multilinguals: $Z = -4.34$, $p < .001$, $M = 62.7 \pm 2.6$ vs. 64.6 ± 3.3 months),
- spoke more often German and less often other languages at home: $Z = -2.50$, $p = .012$ (again, children speaking German were younger than children speaking other languages at home: $Z = -2.06$, $p = .003$, $M = 63.7 \pm 3.1$ vs. 64.9 ± 3.4),
- had more often mothers whose first language was German: $Z = -2.35$, $p = .019$ (such children were younger than children whose mothers acquired other languages than German as their first language: $Z = -4.50$, $p < .001$, $M = 62.9 \pm 2.8$ vs. 64.8 ± 3.3),
- were more often non-migrants than migrants: $Z = -2.57$, $p = .010$ (non-migrants were younger than migrants: $Z = -4.97$, $p < .001$; $M = 62.5 \pm 2.5$ vs. 64.7 ± 3.3).

Regarding biological sex, there was only one significant result for the variables mentioned above: children whose mothers acquired German as their first language were more often girls (44/86 (51.2%)), whereas children of mothers who acquired other languages were more often boys (110/178 (61.8%)): $\chi^2_{(1)} = 3.99$, $p = .046$. As was mentioned in the Introduction, girls tend to have a higher pitch than boys.

Friedman test showed that, again, pitch was very unstable within KiSS.2 non-words ($\chi^2_{(6)} = 53.15$, $p < .001$), KiSS.2 sentences ($\chi^2_{(2)} = 45.65$, $p < .001$), and QUNW ($\chi^2_{(5)} = 60.68$, $p < .001$).

Discussion

No direct associations between children's pitch (F0) and their German language skills were found in both samples (four- and five-year-old children). However, in the subgroup of four-year-old bi-/multilinguals, children with a higher pitch had slightly lower total scores of correct answers in KiSS.2 than children with a lower pitch, which means somewhat weaker German language skills. Also, for the sample of four-year-olds, kindergarten teachers described children with a higher pitch more often as lagging behind in the German language acquisition. However, in other questionnaire items, they did not provide any reason for this subjective estimation.

Several explanations for weaker German language skills of four-year-old children with a higher pitch are conceivable. First, there was a marginally significant link to the age of the German language acquisition. Successive bilinguals had a somewhat higher pitch than simultaneous bilinguals. Since successive bilinguals acquired German under unfavourable sociodemographic conditions (cf. Meisel, 2009; Tsimpli, 2014), it might have resulted in weaker German language skills. Among other things, successive bilinguals were more often immigrants, which usually means (in Germany) a lower socioeconomic status and a lower educational level of parents (DESTATIS et al., 2024). Indeed, the second explanation refers to the lower educational level of parents. It was shown that children of parents with a lower educational level had a higher pitch. According to numerous studies conducted all over the world, children of parents with a lower socioeconomic status, including a lower educational level, tend to have a lower body weight (Aurino et al., 2023; Jarosz & Gugushvili, 2020; Martin et al., 2020), and a lower body weight is sometimes associated with a higher pitch (which explains why children have a higher pitch than adults). However, there is also sometimes no direct, statistically significant link between Body-Mass-Index or weight or height and F0 (Brockmann-Bauser et al., 2015). Third, it cannot be excluded that the association between weaker German language skills (in the sample of four-year-old children) and a higher pitch existed only in the imagination of kindergarten teachers and resulted from a lower socioeconomic status of children with a higher pitch. Fourth, it is well-known that a higher

pitch is used for questions, in the rising intonation (cf. Brinckmann & Benzmüller, 1999). Since children with weaker German language skills or with a weaker memory were more often unsure about their repetition performance, it may well be that they repeated non-words and sentences more often in the form of questions. For German, it means that they used more often rising intonation with a higher pitch.

In contrast to the German language skills, the link between pitch and phonological short-term memory was more prominent in four-year-old children. Although still very weak, there was a tendency that children with a low pitch showed better repetition performance (that was used to quantify the phonological short-term memory). Because children with a lower pitch had parents with a higher educational level, it can be assumed that such children sometimes had better cognitive skills (cf. McDorman et al., 2025; Waters et al., 2025), including memory (cf. Assari, 2020; Zhao et al., 2023).

Among five-year-old children, no associations between pitch and the German language competence were found. Since monolingual Germans were, on average, two months younger than bi-/multilinguals, they had a higher pitch. Due to this link to the variable "monolinguals vs. bi-/multilinguals", children with a higher pitch possessed sociodemographic characteristics associated with speaking German at home. However, because of the age difference between monolinguals and bi-/multilinguals (and in all other variables related to this one), these characteristics did not result in better German language skills of children with a higher pitch. Also, it should be considered that the sample of five-year-olds was much smaller than that of four-year-olds and therefore it was more difficult for statistical tests to yield significant results. In a larger sample, it is highly likely that under the same conditions children with a higher pitch (monolingual Germans) would show better German language competence than children with a lower pitch (bi-/multilinguals), in spite of age differences. There was one interesting exception regarding associations between pitch and KiSS.2 results: slightly better KiSS.2 results in the subgroup of bi-/multilinguals were shown by children with a lower pitch in the repetition of sentences (Table A6 in the Appendix). This is the only evidence from the sample of five-year-old children that confirms findings of the sample of four-year-olds (in which bi-/multilinguals with a lower pitch showed slightly better German language skills).

In the subgroup of five-year-old monolinguals, some correlations between language subtests and pitch had coefficients > .2 (Table A6 in the Appendix) that would become statistically significant in larger samples. However, in this case better German language competence correlated with higher pitches. It shows that no general, default association between language skills and pitch exists. Instead, better German language competence can be associated either with higher or with lower pitches depending on which subgroups of children happened to have a better access to the German language input, that is, had a higher quality and/or quantity of the German language input.

In five-year-olds, there was no link between pitch and the phonological short-term memory. It is valid both for German-based and language-independent non-words as well as for sentences. It is also valid both for monolingual Germans and bi-/multilinguals. The explanation can be, among other things, the missing (not statistically significant) link to the parents' educational level and, thus, indirectly, to missing differences in children's cognitive skills.

Generally, associations between pitch and sociodemographic or medical characteristics were very weak to non-existent. One of the explanations for this phenomenon was the instability of pitch. Friedman tests demonstrated that children changed their pitch highly significantly within

tasks. Also, there were two confounding factor among four-year-olds that might have distorted the results, namely comparatively low pitches of (a) Arabic-speaking children who are well-known for their poor German language skills in Germany (Zaretsky & Lange, 2023), (b) bi-/multilinguals who had peers speaking the same non-German language in the kindergarten group – another factor that slows down the pace of the German language acquisition (Zaretsky & Lange, 2017). Thus, whereas other bi-/multilinguals with poor German language skills had higher pitches, Arabic-speaking children (the largest subgroup of bi-/multilinguals) as well as children with non-German-speaking peers happened to have lower pitches. Thus, there were two large exceptions to the rule. Since Arabic-speaking children in Germany have more often overweight than most other children (Fahrun, 2008; Misslbeck, 2009), this can be a physical explanation for their lower pitch.

Mean pitch values of children in the present study were somewhat lower than 300 Hz and, thus, typical for children. Pitch values of five-year-old children were lower than those of four-year-olds. There were no unexpected findings in this respect. More surprising were missing correlations between pitch and well-known sociodemographic characteristics such as age (in four-year-olds) and biological sex. It can be explained by the narrow age span (12 months) and minimal differences between boys and girls in pitch at this age. Indeed, some studies showed that differences between boys and girls in F0 tend to appear at a later age (Nagels et al., 2020; Whiteside & Hodgson, 2009). In five-year-olds, as expected, older children (in months) had a lower pitch.

Conclusion

To sum up, the link between pitch and German language skills was very weak and can be found only in the subgroup of four-year-old bi-/multilinguals: here, children with a higher pitch had a slightly weaker language competence. In the whole sample of four-year-olds, a higher pitch was only associated with the (minimally) weaker phonological short-term memory, with vague links to the lower educational level of parents and other unfavourable sociodemographic conditions. Among five-year-olds, there were no associations between pitch and German language competence as well as the phonological short-term memory.

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

The authors declare that no AI or AI-assisted technologies have been used to generate, refine, or correct the content in 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

Table A1

Pitch (F0) of All Items: Four-Year-Old Children

Items	Minimum	Maximum	*M* ±SD
Gune	160	554	269.5 ±38.9
Meling	179	437	273.5 ±37.7
Flome	168	427	277.9 ±38.5
Triser	192	530	279.6 ±42.2
Schabu	164	454	273.0 ±38.6
Feilister	166	525	274.3 ±39.4
Posalin	189	573	292.9 ±46.7
Zibu	176	435	284.7 ±40.7
Lita	170	427	280.7 ±40.8
Maki	174	530	284.4 ±41.5
Luni	189	458	279.4 ±39.6
Sipula	179	415	281.5 ±39.2
Malitu	181	448	278.4 ±36.2
Die Enten fressen am See.	181	475	279.8 ±36.1
Das Telefon klingelt den ganzen Morgen.	185	463	274.2 ±36.1
Max kauft ein Eis.	160	554	269.7 ±36.9

Note. *M* mean, SD standard deviation

Table A2

Pitch (F0) of Four-Year-Old Monolingual German and Bi-/Multilingual Children

	Monolingual Germans *M* ±SD	Bi-/multilinguals *M* ±SD
KiSS.2 non-words	274.4 ±32.6	274.8 ±34.1
KiSS.2 sentences	277.2 ±32.8	278.3 ±33.2
"Quasi-universal" non-words	285.7 ±34.3	283.6 ±39.0
Total	279.5 ±30.8	279.1 ±31.8

Note. *M* mean, SD standard deviation

Table A3

Associations Between Pitch (F0) and Total Scores of Correct Answers in Language Tests (Four-Year-Old Children)

Language tests	Pitch: KiSS.2 non-words	Pitch: KiSS.2 sentences	Pitch: QUNW	Pitch: all tasks
All children				
KiSS.2: speech comprehension	-.040	-.097*	-.046	-.060
KiSS.2: vocabulary	.017	-.022	.031	.015
KiSS.2: articulation	-.056	-.072	-.076	-.074
KiSS.2: grammar	-.018	-.065	.004	-.013
KiSS.2: repetition of non-words	-.088*	-.074	-.127*	-.113**
KiSS.2: repetition of sentences	-.052	-.104*	-.065	-.085
KiSS.2: total score	-0.32	-.087	-.038	-.057
"Quasi-universal" non-words	-.104*	-.110*	-.154**	-.140**
Monolingual Germans				
KiSS.2: speech comprehension	-.064	-.138	-.113	-.107
KiSS.2: vocabulary	-.036	-.035	-.016	-.031

KiSS.2: articulation	-.097	-.122	-.052	-.096
KiSS.2: grammar	-.023	-.035	-.040	-.030
KiSS.2: repetition of non-words	-.015	-.036	-.059	-.031
KiSS.2: repetition of sentences	-.041	-.113	-.043	-.073
KiSS.2: total score	-.052	-.087	-.064	-.068
"Quasi-universal" non-words	-.085	-.202**	-.126	-.144*
Bi-/multilinguals				
KiSS.2: speech comprehension	-.038	-.095	-.072	-.072
KiSS.2: vocabulary	.014	-.032	-.032	-.020
KiSS.2: articulation	-.038	-.044	-.099	-.071
KiSS.2: grammar	-.035	-.113	-.047	-.069
KiSS.2: repetition of non-words	-.136*	-.097	-.159**	-.157**
KiSS.2: repetition of sentences	-.091	-.134*	-.163**	-.153**
KiSS.2: total score	-.062	-.129*	-.116*	-.115*
"Quasi-universal" non-words	-.116*	-.042	-.139*	-.125*

Note. *** $p < .001$, ** $p < .01$, * $p < .05$; QUNW "quasi-universal" non-words; Spearman's correlations

Table A4

Pitch (F0) of All Items: Five-Year-Old Children

Items	Minimum	Maximum	*M* ±SD
Gune	152	440	269.3 ±35.9
Meling	194	483	262.8 ±36.8
Flome	198	484	266.5 ±36.6
Triser	183	580	271.1 ±41.4
Schabu	194	553	269.5 ±41.0
Feilister	194	539	263.8 ±39.8
Posalin	201	443	263.5 ±34.2
Zibu	186	452	278.0 ±38.8
Lita	202	462	273.9 ±39.0
Maki	186	505	269.5 ±41.6
Luni	192	504	272.1 ±37.6
Sipula	168	473	270.3 ±38.3
Malitu	201	492	269.7 ±35.9
Die Enten fressen am See.	175	589	275.5 ±43.5
Das Telefon klingelt den ganzen Morgen.	197	469	274.1 ±34.5
Max kauft ein Eis.	194	526	268.3 ±39.9

Note. *M* mean, SD standard deviation

Table A5

Pitch (F0) of Five-Year-Old Monolingual German and Bi-/Multilingual Children

	Monolingual Germans *M* ±SD	Bi-/multilinguals *M* ±SD
KiSS.2 non-words	273.8 ±40.5	264.7 ±29.7
KiSS.2 sentences	278.9 ±42.6	270.9 ±31.5
"Quasi-universal" non-words	281.1 ±40.9	270.0 ±31.1
Total	277.9 ±38.7	268.6 ±28.5

Note. *M* mean, SD standard deviation

Table A6

Associations Between Pitch (F0) and Total Scores of Correct Answers in Language Tests (Five-Year-Old Children)

Language tests	Pitch: KiSS.2 non-words	Pitch: KiSS.2 sentences	Pitch: QUNW	Pitch: all tasks
All children				
KiSS.2: speech comprehension	-.091	-.065	-.070	-.081
KiSS.2: vocabulary	.016	-.068	.032	.000
KiSS.2: articulation	-.030	-.093	-.027	-.054
KiSS.2: grammar	.029	-.041	.050	.023
KiSS.2: repetition of non-words	-.016	-.064	-.040	-.041
KiSS.2: repetition of sentences	.086	-.065	.063	.036
KiSS.2: total score	.035	-.060	.044	.014
“Quasi-universal” non-words	-.024	-.057	.001	-.027
Monolingual Germans				
KiSS.2: speech comprehension	-.154	.038	-.121	-.075
KiSS.2: vocabulary	.018	-.045	.039	.001
KiSS.2: articulation	.068	-.018	.179	.078
KiSS.2: grammar	.076	.125	.060	.111
KiSS.2: repetition of non-words	.204	.162	.230	.216
KiSS.2: repetition of sentences	.137	.065	.078	.094
KiSS.2: total score	.181	.176	.171	.202
“Quasi-universal” non-words	.051	.066	.052	.087
Bi-/multilinguals				
KiSS.2: speech comprehension	-.123	-.115	-.104	-.126
KiSS.2: vocabulary	-.044	-.136*	-.045	-.072
KiSS.2: articulation	-.076	-.130*	-.103	-.107
KiSS.2: grammar	-.054	-.138*	-.052	-.081
KiSS.2: repetition of non-words	-.081	-.133*	-.121	-.121
KiSS.2: repetition of sentences	.010	-.157*	-.023	-.059
KiSS.2: total score	-.059	-.167*	-.070	-.103
“Quasi-universal” non-words	-.016	-.067	.026	-.021

Note. *** $p < .001$, ** $p < .01$, * $p < .05$; QUNW “quasi-universal” non-words ; Spearman’s correlations