LINGUISTIC CRITERIA FOR SELECTING SENTENCES FOR A HEARING IN NOISE TEST FOR CHILDREN

An observational and cross-sectional study

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LIST OF ABBREVIATIONS AND RELEVANT DEFINITIONS

AoA	Age of Acquisition
dB	Decibel
dBA	A-weighted decibels
dBHL	Decibel Hearing Level
F0	Fundamental frequency
HINT	Hearing In Noise Test
IC	Informed Consent
Mdn	Median
OR	Odds Ratio
OVS	Object – Verb – Subject
PPVT	Peabody Picture Vocabulary Test
SPSS	Statistical Package for the Social Sciences
SOV	Subject – Object – Verb
T-TOS	Dutch language test: Testinstrumentarium Taalontwikkelingsstoornissen
UMCU	University Medical Center Utrecht
UMCU-HINT	Hearing in noise test using sentences read by the female speaker of the University Medical Center Utrecht
VU	VU medical center
VU-HINT	Hearing in noise test using sentences read by the female speaker of the VU Medical center

SAMENVATTING

Achtergrond: De accuraatheid waarmee een zin wordt nagezegd wordt beïnvloed door de complexiteit ervan. Taalkundige criteria zijn echter nog niet meegenomen bij het selecteren van zinsmateriaal voor spraak-in-ruistesten voor kinderen.

Doel en onderzoeksvraag: Dit onderzoek beoogt zinsmateriaal te selecteren voor een spraak-in-ruistest voor kinderen op basis van taalkundige criteria. De onderzoeksvraag luidt: Welke lexicale en grammaticale parameters beïnvloeden de accuraatheid waarmee zinnen worden nagezegd door zich normaal ontwikkelende, zesjarige kinderen tijdens een zinsrepetitietaak met zinnen uit een Nederlandse spraak-in-ruistest?

Methode: Dit onderzoek is observationeel en cross-sectioneel. Zesjarige kinderen (*N* = 40) voerden een zinsrepetitietaak uit met zinnen afkomstig uit een spraak-in-ruistest voor volwassenen. De taalkundige complexiteit van de zinnen was vooraf gedefinieerd met een lexicale en vier grammaticale parameters, respectievelijk woordverwervingsleeftijd en zinslengte, voorzetsels, zinsstructuur en werkwoordvervoeging. De analyse bestond uit een logische regressieanalyse.

Resultaten: Zinnen met een hogere woordverwervingsleeftijd (*OR* = 1.615) en langere zinnen (*OR* = 1.309) hadden een significant groter risico op incorrecte zinsrepetitie. Zinnen met een ruimtelijk voorzetsel (*OR* = 1.254) of ander voorzetsel (*OR* = 1.229) hadden ook een groter risico om verkeerd nagezegd te worden, evenals samengestelde zinnen (*OR* = 1.630) en zinnen in de voltooide tijd (*OR* = 1.474) of toekomstige tijd (*OR* = 2.538).

Conclusie: De accuraatheid waarmee zinnen uit een spraak-in-ruistest worden nagezegd door zesjarige kinderen wordt significant beïnvloed door zowel lexicale als grammaticale parameters, te weten: woordverwervingsleeftijd, zinslengte, voorzetsels, zinsstructuur en werkwoordsvervoeging.

Aanbevelingen: Taalkundige criteria zouden in overweging moeten worden genomen bij het selecteren of creëren van zinsmateriaal voor gehoortesten voor kinderen. Alvorens de nieuwe, Nederlandse zinslijsten te implementeren in de klinische praktijk, is het van belang dat vervolgonderzoek gericht is op het valideren en standaardiseren van de zinslijsten voor spraak-in-ruistesten. Het ontwikkelen van extra zinsmateriaal is mogelijk nodig.

Kernwoorden: gehoor, kinderen, diagnose, linguïstiek, spraakperceptie

ABSTRACT

Background: Hearing In Noise Tests have been developed for children without considering the linguistic complexity of the sentences used. However, linguistic complexity influences correct sentence repetition.

Aim and research questions: This study aims to identify linguistic parameters influencing sentence repetition accuracy to select sentences for a Dutch Hearing In Noise Test for children. The research question is: What lexical and grammatical parameters influence verbal repetition accuracy of sentences derived from a Dutch Hearing In Noise Test when performed by 6-year-old, typically developing children?

Method: For this observational, cross-sectional study, 40 children aged 6 performed a sentence repetition task derived from a Hearing In Noise test for adults. The sentence complexity was described beforehand with one lexical parameter, age of acquisition, and four grammatical parameters, specifically sentence length, prepositions, sentence structure and verb inflection. A multiple logistic regression analysis was performed.

Results: Sentences with a higher age of acquisition (*OR* = 1.615) or greater sentence length (*OR* = 1.309) had a higher risk of verbal inaccuracy. Sentences including a spatial (*OR* = 1.254) or other preposition (*OR* = 1.229) were at increased risk for incorrect repetition, as were complex sentences (*OR* = 1.630) and sentences in the present perfect (*OR* = 1.474) or future tense (*OR* = 2.538).

Conclusion: The variation in verbal repetition accuracy in 6-year-old children is significantly influenced by both lexical and grammatical parameters, specifically: age of acquisition, sentence length, prepositions, sentence structure and verb inflection.

Recommendation: Linguistic criteria should be considered when selecting or creating sentences for hearing tests for children, in order to prevent biased test results. Before implementing the new, Dutch sentence lists in clinical practice, future research should focus on validation and standardisation of these lists. Creation and recording of additional sentences may be necessary.

Keywords: hearing, children, diagnosis, linguistics, speech perception

INTRODUCTION

It is estimated that 0.5% to 1% of all school children experience difficulties listening in noisy environments, causing them to lose focus during auditory instructions.[1] Subsequently, auditory complaints have been associated with poor literacy skills and low academic performance.[1–3] Children who experience listening difficulties undergo tone audiometry, speech audiometry or both to evaluate their hearing function.[4] However, sufficient performance on these hearing assessments does not guarantee normal hearing function, especially in noisy environments, as these tests are performed in silence.[3,5] Background noise complicates real-life listening situations. Therefore, a Hearing In Noise Test (HINT) is advised for diagnosing listening difficulties, as it emulates daily life situations with background noise.[6]

During a HINT, everyday sentences are required to repeat with and without noise.[7] HINTs are available in many languages for adults.[4,8–11] In some languages (such as English, Norwegian, Brazilian and Korean), HINTs have been developed for children, as a subset of the adult test.[4,7,12,13] Plomp and Mimpen[14] have developed a Dutch HINT for adults containing 130 sentences. The VU developed its successor, the VU Medical Center HINT (VU-HINT), which contains 507 sentences.[6] Pape[15] has used the Plomp and Mimpen test to select Dutch sentence material for children, although this selection only resulted in 30 sentences. Papes' number is not large enough for clinical practice nor has the selection been validated.[6] The VU-HINT contains a larger number of sentences, but a selection of these 507 sentences for children has not yet been made.

In the absence of a validated Dutch HINT specifically for children, the Dutch HINT for adults is sometimes used to diagnose listening difficulties in children. However, this method ignores the differences between children's and adults' speech perception.[6] Children's speech perception improves with age and is influenced by their cognitive and language development.[16,17] Additionally, differences between speakers who read test-sentences have been suggested to affect intelligibility, even when using the same sentence material. That said, this difference has not yet been investigated in children.[6]

Nevertheless, differences in sentence complexity can influence the outcomes of HINTs.[15,26] Both lexical and grammatical factors have been found to influence correct sentence repetition for adults, with noise increasing this effect.[14] Although children with better language skills have demonstrated better performance on HINTs[27,38], linguistic criteria have been overlooked in the development of many HINTs, including the VU-HINT.[4,6,8,12,20–23] Rather, sentences were selected based on the subjective criterion of being representative of everyday language. The impact of sentence complexity on HINT outcomes has not yet been investigated in children, but it is hypothesised to be even greater. It is therefore unclear whether children's performances on HINTs reflect their audiologic abilities or if the test results are affected by varying sentence complexity.

The aim of this study is to identify linguistic parameters influencing sentence repetition accuracy in order to select sentences for the development of a HINT for children. The following research questions are addressed:

- What lexical and grammatical parameters influence verbal repetition accuracy of sentences derived from a Dutch HINT when performed by 6-year-old typically developing children?
- Which sentences from the VU-HINT are appropriate to use for the development of a HINT for children aged 6 and older?

MATERIALS AND METHODS

Design

This study follows an observational, cross-sectional, psychometric design.

Participants

The study population consisted of Dutch, 6-year-old, typically developing children. Four primary schools, located in the middle and south of the Netherlands, were selected. At these schools, all 6-year-old children were invited to participate in the study using an advertisement in their schools' newsletter.

Recruitment took place from December 2017 to April 2018. Children were included if they were 6 years of age and had normal hearing levels in at least one ear, defined as hearing thresholds ≤ 20 dBHL for frequencies between 250-8000 Hertz. Third, performance within normal limits was required on two language tests: the Peabody Picture Vocabulary Test (PPVT) and the sentence repetition task from the *Testinstrumentarium taalontwikkelingsstoornissen* (T-TOS). [24,25] The language test performances were interpreted within normal limits if the standardised test scores were within 1 standard deviation (sd) from the mean. Children with attention or learning deficits were excluded to prevent a gap between a child's individual competencies and the competencies he or she demonstrated on the tests.[26–29]

Procedures

Children participated in one or two 30-minute sessions that were conducted in a separate room in their primary school. During the first session, three tests were performed to determine their eligibility for the study. If eligible, the sentence repetition task was performed a week later.

During the first session, tone audiometry was performed to determine children's hearing thresholds for both ears. The PPVT was used to assess passive vocabulary skills and the sentence repetition task from the T-TOS was conducted to investigate children's ability to recall and reproduce sentences.[24,25] Both language tests have been proven reliable with sufficient structural validity.[24,30]

In terms of the repetition task, sentences were played monaurally at a level of 60 dBA using a Sennheiser HD 200 headphone, a laptop and an ESI - U24 XL sound card.[31] During the experiment, an audio-recorder was utilised to improve the study verifiability. Recorder use also allowed the researcher to conduct the transcription and analysis after the experiment, enabling focus on motivating the children during the experiment. If a child lost focus, the experiment was paused. Throughout the experiment, children were motivated with a game. After repeating 10 sentences, the child earned a rabbit-toy. If all 10 rabbits were earned, the child could play the game with the researcher.

The experiment was conducted with a selection of the original female-read sentences of the VU-HINT[6] and the female-read sentences of the UMCU-HINT. The UMCU-HINT sentences are the same as the VU-HINT sentences, but are spoken by a different female speaker.

Children were asked to repeat 100 sentences, 50 from the VU-HINT and 50 from the UMCU-HINT. To prevent information bias introduced by sequence effects, each child's sentences were selected by using a random sequence generator. Moreover, half of the children began with sentences spoken by the VU's female speaker, while the other half started with sentences from the UMCU's female speaker.

The transcription and analysis took place after the experiment using the audio-recordings. The first two audio-recordings, totalling 200 sentences, were assessed independently by two researchers. The other transcriptions were completed by a single researcher who was not blinded for the linguistic parameters.

Variables

The dependent variable of this study was repetition accuracy per sentence (binary). The predictors consisted of one lexical and four grammatical parameters (Table 1). Lexical complexity was described by the Age of Acquisition (AoA) for the most difficult word in the sentence.[32] Four parameters accounted for grammatical complexity: (1) sentence length in terms of the number of words, (2) presence or absence of a preposition, (3) syntactic structure and (4) type of verb inflection. In the statistical analysis, the speaker in the audio-recording was considered a potential confounder.

Data sources

Linguistic parameters

Linguistic parameters were derived from the literature.[18,19,33] The SUBTLEX database, a database of 30,000 Dutch words with AoA ratings and word frequency ratings developed for research purposes, was used to determine AoA rating.[32] This data-base has illustrated a high level of internal consistency (*ICC* = .93). Although the SUBTLEX database was developed in Belgium, an earlier pilot study has confirmed its applicability for Dutch contexts.[34]

Sentence-selection

The VU-HINT consists of 507 sentences; however, not all sentences were included in this study. Before the experiment was conducted, a pre-selection of these sentences was made. Sentences including a word with an AoA > 9.5 were excluded from this study. This criterion was based on a retrospective analysis of a study conducted by Pape[15] that aimed to select Dutch sentence material for children between 6 to 9 years of age. This analysis indicated a significantly lower AoA for the children's selection (*Mdn* = 6.78) than in the total list (*Mdn* = 7.26), where T = 1275.00, p < .001, r = .456. In addition, the selected sentences did not contain words with an AoA > 9.5. Based on this criterion, 70 sentences were excluded during the pre-selection process, resulting in 437 sentences included in the present study.

Statistical methods

All statistical analyses were conducted using the Statistical Package for the Social Sciences (SPSS) Statistics version 25.0 (Armonk New York USA). Descriptive statistics were used to describe characteristics of both participants and sentences.

The minimum number of sentences required for this study was calculated at 2250, since it is recommended to have at least 30 events per (category of a) variable.[35] An event (incorrect sentence repetition) was expected to occur in 20% of the sentences.

Mann-Whitney U tests were conducted to analyse differences between the speakers in the VU-HINT and UMCU-HINT regarding three speech characteristics.[36] First, audio recording duration provided information about the speakers' rate of speech. Second, the fundamental frequency (F0) represented the speakers' pitch. Third, the variance in F0 revealed information concerning the speakers' intonation.

The interrater reliability was calculated using the Kappa coefficient, where strong agreement between the two researchers was defined as $\kappa > .8$.

A multivariate logistic regression analysis was conducted using the enter method. For each variable, the expected 'least risk' category served as the reference category (Table 1). Risk factors were expressed as odds ratio's (OR), with 95% confidence intervals (CI) and *p*-values. To place the risk factors into perspective, any significant differences between the estimates of risk were analysed. Therefore, the variable 'speaker' was added to the regression model, and interactions between the language parameters and 'speaker' were examined. If an interaction term was not found to be significant ($p > .05$) it was removed.

Based on the multivariate logistic regression analysis, sentences were selected. A sentence was removed if:

- it contained a high value for a continuous variable that was significantly associated with repetition mistakes;
- it contained one or more categorical linguistic parameters that significantly increased the risk of inaccuracy in verbal repetition;
- it was repeated incorrectly by more than 50% of participants.

After the selection was completed, the remaining sentences were divided into 10 lists. The sentences were evenly distributed based on continuous variables that significantly increased the risk of incorrect repetition.

RESULTS

Participants

Of the 67 children who were contacted to participate in the study, 49 cases provided informed consent (Figure 1). Children who were not 6 years of age during the experiment (*n*=3) were excluded. Additionally, five children were excluded either because they scored below average (*n*=1) or above average (*n*=4) on the language tests. One case was excluded as a result of binaural hearing thresholds above 20 dBHL.

Fourty children (mean age 77 months; range 72-83; 47.5% female) completed the experiment (Table 2). Six children (15.4%) were raised bilingually and spoke Dutch and either Moroccan Arabic (*n* = 3), German (*n* = 2) or French (*n* = 2). Parents reported a history of ear problems, such as ear infections, in eight children.

Speakers

The duration of the VU audio-recordings (*Mdn* = 1.82 seconds) was significantly shorter than that of the UMCU audio-recordings (*Mdn* = 2.35 seconds), $U = 16747.00$, $z = -23.97$, $p < .001$, $r = -.75$. This finding indicates a higher speech rate in the VU audio-recordings.

The fundamental frequency (F0) of the VU audio-recordings (*Mdn* = 174.08 Hertz) was significantly lower than the F0 of the UMCU audio-recordings (*Mdn* = 230.15 Hertz), $U = 1445.00$, $z = -27.25$, $p < .001$, $r = -.86$. This result suggests a lower pitch in the VU audio-recordings.

Finally, the variance in F0 during the recording was greater in the VU audio-recordings (*Mdn* = 1218.69 Hertz) than in the UMCU audio-recordings (*Mdn* = 852.40 Hertz), $U = 82282.00$, $z = -9.92$, $p < .001$, $r = -.31$ This finding demonstrates that the speech in the VU recordings had a greater level of intonation.

Interrater reliability

Two independent researchers scored the sentence repetition task of two participants. Among the 200 sentences, 195 sentences received similar ratings from the two independent researchers. As a result, there was strong agreement between the two ratings, κ= .924, 95% CI [0.858-0.99], p < .001.

Outcome data

Of the 4000 sentences, 980 sentences (24.5%) were repeated inaccurately. The mean number of mistakes per child was 24.5 (range 4-55 mistakes). Of the 437 unique sentences, 372 (85%) were repeated correctly by more than half of the children. There was no missing data since all children completed the sentence repetition task.

The multivariate logistic regression model indicated both lexical and grammatical risk factors for verbal inaccuracy (Table 3). Sentences spoken by the UMCU-speaker were less likely to be repeated incorrectly ($OR = 0.798$, $p = .003$), but the variable 'speaker' did not interact significantly with the lexical parameter and four grammatical linguistic parameters.

A higher AoA significantly increased the risk of incorrect sentence repetition ($OR = 1.587$, $p < .001$). Increased sentence length was associated with a significantly greater risk of verbal repetition mistakes ($OR = 1.282$, $p < .001$). Sentences with a spatial preposition ($OR = 1.248$, $p = .047$) or other preposition ($OR = 1.252$, $p = .023$) were more likely to be repeated incorrectly than sentences without a preposition. The risk of incorrect sentence repetition for sentences with a subject object verb (SOV) structure did not differ significantly from those with an object verb subject (OVS) or passive structure. However, the risk was greater for complex sentences (*OR* = 1.688, *p* = .001). Compared to sentences in the present simple tense, sentences in the present perfect (*OR* = 1.443, *p* = .004) and future tenses (*OR* = 2.315, *p* = .002) had a significantly higher risk of repetition inaccuracy. Sentences in the past tense were not associated significantly with incorrect repetition.

Sentence selection

Of the 437 sentences, 331 were removed based on the logistic regression output (Figure 2). Sentences with an AoA greater than eight (*n* = 113) or a sentence length less than seven (*n* = 37) were removed, as were sentences containing a preposition (*n* = 129). For the parameter, 'sentence structure', complex sentences were removed (*n* = 19). Sentences in the present perfect (*n* = 28) or future tense (*n* = 5) were also removed. Of the remaining 106 sentences, a final 6 sentences were removed because they were repeated incorrectly by more than half of the children. The remaining 100 sentences were divided into 10 lists with similar sentence lengths and AoAs (see Appendix). The mean sentence length in terms of words was 5.6 or 5.7 for all lists, and the mean AoA varied from 6.63 to 6.69.

DISCUSSION

The aim of this study was to identify linguistic parameters that influence sentence repetition accuracy in order to select sentences to develop a HINT for children. Five linguistic parameters were hypothesised to influence the accuracy of verbal repetition for 6-year-old children: age of acquisition, sentence length, presence or absence of a preposition, sentence structure and type of verb inflection. This hypothesis was confirmed for all parameters, both lexical and grammatical.

These findings expand prior work on the effect of linguistic complexity for sentence repetition accuracy.[18,33,37] In agreement with previous research, lexical complexity was found to significantly influence the accuracy of sentence repetition.[19,38] In earlier studies, children with a greater knowledge of vocabulary or stronger lexical-access abilities performed better on HINTs.[27,38] However, to the authors' knowledge, the influence of lexical complexity on sentence repetition accuracy has not been investigated before.

In terms of grammatical parameters, a significant, positive effect of sentence length was identified for repetition accuracy. This finding is consistent with a Dutch study of adults that performed a sentence repetition task in a noisy environment.[19] In addition, sentences that included a preposition were more likely to be repeated incorrectly. This finding is also consistent with international literature.[18,19,39]

Similar to studies conducted with adults, sentence structure significantly affected accurate repetition for children.[18,19,33] However, the category in which the effect was observed differed. In the present study, the risk of repetition mistakes was greater only for complex sentences. However, another Dutch study has indicated that adults struggle to reproduce passive sentences in background noise.[19] Furthermore, two German studies have indicated that the reaction time of adults was significantly longer for OVS-sentences than SOV-sentences, revealing a higher level of difficulty in repeating these sentences.[18,33] This difference could be explained by differences between the Dutch and German language or by the quiet listening environment of the experiment and the noisy environment in other studies.

Furthermore, in the present study, sentences in the present perfect and future tense were associated with greater levels of repetition inaccuracy. This result aligns with English, German and Dutch studies that have suggested specific difficulties with repeating verbs in HINTs.[18,19,39] Contrary to the literature, past tense sentences were not associated with a greater number of repetition mistakes in the present study.[18,19,39] This discrepancy might have been caused by the quiet environment in the experiment and the noisy environment in other studies. More specifically, Dutch verbs in the past tense are characterised by adding an unstressed syllable to the verb (-*de* or -*te*), and unstressed syllables are often omitted in noisy test situations.[19] Therefore, performing the same experiment in background noise may produce different results. Simple past sentences may therefore be appropriate to use in a HINT for children, but this conclusion should be confirmed with an experiment in background noise.

After considering the results for all five linguistic parameters, the sentence selection procedure was completed. This procedure resulted in selection of 100 sentences of the total 507 sentences (20%). The percentage of sentences selected in this study is lower than percentages reported in other studies, including those of Pape[15] (40%) and Myhrum et al.[12] (50%). It is difficult to compare the sentence selection strictness in such studies, because the studies included children of different ages, and the linguistic complexity of the original materials may differ. However, including linguistic criteria in the sentence selection is expected to limit the number of selected sentences.

A total of 100 sentences may be sufficient for most clinical practices, although in some situations, more sentence lists may be needed. For example, more sentence lists may be required to investigate the effects of adjustable hearing aid parameters or serve clinical research purposes.[6] Consequently, there is a need for development of additional sentence material according to the new findings about linguistic complexity. Creation and recording of additional sentences was beyond the scope of this research, as was investigating whether the sentence selection could be broadened for other populations, such as older children.

The repetition task of the present study included two female speakers. A higher level of repetition accuracy was observed in sentences spoken by the UMCU-speaker as compared to the VU-speaker. An earlier study has also indicated variation in the repetition accuracy of identical sentences spoken by different speakers.[6] Particular aspects that led to differences in repetition accuracy cannot be specifically indicated, as the two speakers' speech differed in many ways. The difference in duration might have played a role, since children better understand sentences spoken with a lower speech rate.[40]

Notably, while the risk of verbal repetition inaccuracy was higher for sentences spoken by the VU-speaker, the linguistic parameters estimates were unrelated to the speaker of the sentence. The linguistic parameters are therefore more robust. Strengths of this study are the sample size ($N = 40$) and the experiment size (100 sentences), which were relatively large. The results are therefore based on repetition outcomes of 4000 sentences. Furthermore, the generalizability of this study is sufficient, since the study sample covered the whole range of age (in months) and language scores; likewise, it also included bilingual children.

There were some limitations worth noting. First, the hearing screening and experiment were conducted in separate rooms of primary schools, rather than in a compliant, sound-treated environment. This environment was not expected to create measurement bias, since a standardised headphone was used.[31] This headphone accounts for sufficient attenuation of background noise up to 28 dB. In addition, the experiment was paused during noisy moments such as children's play breaks. As a result, the audio-recording was always audible for the child. Under these same conditions, a prior study has concluded that diagnostic audiometry can be reliably performed at schools without performing a correction.[41] Second, most audio-recordings in this study were assessed by one researcher. Because this researcher was not blinded for the measurement and outcome assessments, a risk for bias was created. However, the first two audio-recordings were also assessed by an independent researcher, and strong inter-rater reliability was determined ($\kappa = .924$, $p < .001$).

RECOMMENDATIONS

These results provide convincing evidence for linguistic parameters being important to consider when selecting sentences for a children's Dutch HINT. It is recommended to use the new sentence lists for children aged 6 and older. Future research should therefore include validation and standardisation of these sentence lists. The linguistic parameters should also be evaluated with noise, since their effects are expected to be greater in noise and might even be different.[19] Creation and recording of additional sentences may also be needed. The presented method of selecting sentences for a HINT could also be used to develop HINTs for children in other languages.

These findings may have direct implications for audiologic practice. Current interpretations of a child's HINT performance that overlook linguistic factors might lead to biased results. A child's performance on a HINT should thus require careful interpretation, performed by, for example, a speech therapist or clinical linguist. It is also recommended that those interpreting the results compare a child's HINT performance with a test that includes word stimuli or digits, such as the digits-in-noise test.[42]

CONCLUSION

This study demonstrates that the accuracy of verbal repetition for 6-year-old children is significantly influenced by lexical and grammatical parameters, specifically: age of acquisition, sentence length, prepositions, sentence structure and verb inflection. Based on these findings, 100 sentences (20%) were selected from the HINT for adults to develop a Dutch HINT for children.

ETHICAL APPROVAL

All parents received written information about the study and were required to provide written informed consent. The ethics committee at the UMCU declared that no formal approval of the detailed protocol was needed according to the Dutch Medical Research Involving Human Subjects Act (No.14-850/C).

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TABLES

Table 1

Characteristics of sentences (n = 437) derived from the VU-HINT

Parameter	Distribution
Age of Acquisition mean (range;sd)	7.14 (4.17-9.5; 1.21)
Sentence length mean (range;sd)	6.19 (4-9; 0.95)
Preposition *n* (%)	
1= No preposition	228 (52.2)
2= Yes, spatial	92 (21.1)
3= Yes, other	117 (26.8)
Syntactic structure *n* (%)	
1 = SOV	301 (59.5)
2 = OVS	80 (13.3)
3 = Passive	22 (5)
4= Complex	34 (7.8)
Verb inflection *n* (%)	
1= Present simple	260 (59.5)
2= Past tense	104 (23.8)
3= Present perfect	65 (14.9)
4= Future tense	8 (1.8)

Note. VU-HINT = Hearing In Noise Test developed by the VU medical center; SOV = Subject Object Verb; OVS = Object Verb Subject

Table 2

Characteristics of the study group (N = 40)

Variable	**Included children**
Age in months mean (range;sd)	77.55 (72-83; 3.69)
PPVT quotient score mean (range;sd)	102.29 (86-115; 8.52)
Gender *n* (%)	
Male	21 (52.5)
Female	19 (47.5)
Language acquisition *n* (%)	
Monolingual	33 (84.6)
Bilingual	6 (15.4)
History of ear problems *n* (%)	
No	32 (80)
Yes	8 (20)

Note. Sd = standard deviation; PPVT = Peabody Picture Vocabulary Test

Table 3

Output of the logistic regression analysis describing risk estimates for repetition inaccuracy

Parameter	OR[a]	95% CI	Sig
Age of acquisition	1.587	[1.486, 1.696]	.000*
Sentence length	1.282	[1.168, 1.407]	.000*
Preposition			
No			
Spatial	1.248	[1.003, 1.553]	.047*
Other	1.252	[1.032, 1.520]	.023*
Syntactic structure			
SOV			
OVS	0.920	[0.748, 1.131]	.428
Passive	0.779	[0.526, 1.154]	.212
Complex	1.688	[1.241, 2.297]	.001*
Verb inflection			
Present simple			
Past tense	1.129	[0.939, 1.356]	.197
Present perfect	1.443	[1.123, 1.855]	.004*
Future tense	2.315	[1.376, 3.895]	.002*
Speaker (1)	0.798	[0.687, 0.927]	.003*

Note. OR = odds ratio; CI = confidence interval; sig = significance level; SOV = Subject Object Verb; OVS = Object Verb Subject

[a] The five linguistic parameters and speaker-variable were entered simultaneously

* $p < .05$

FIGURES

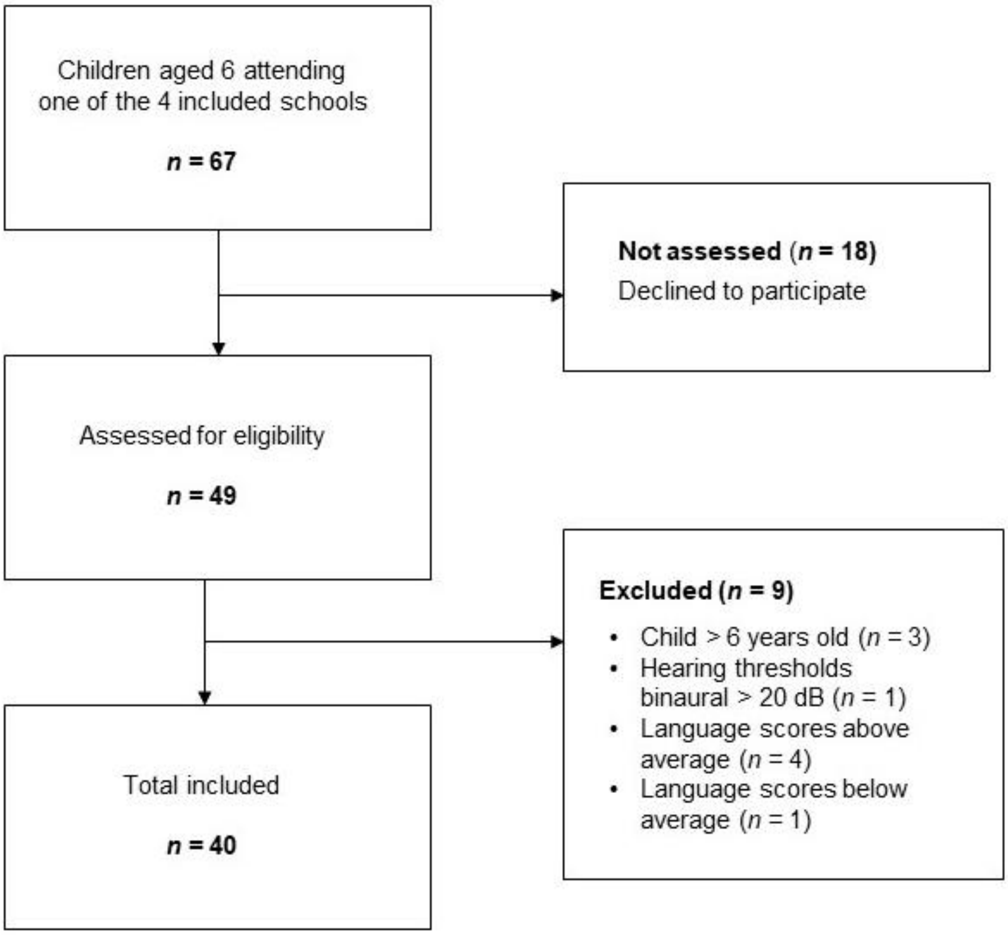

Figure 1. Flow chart of the selection of study participants

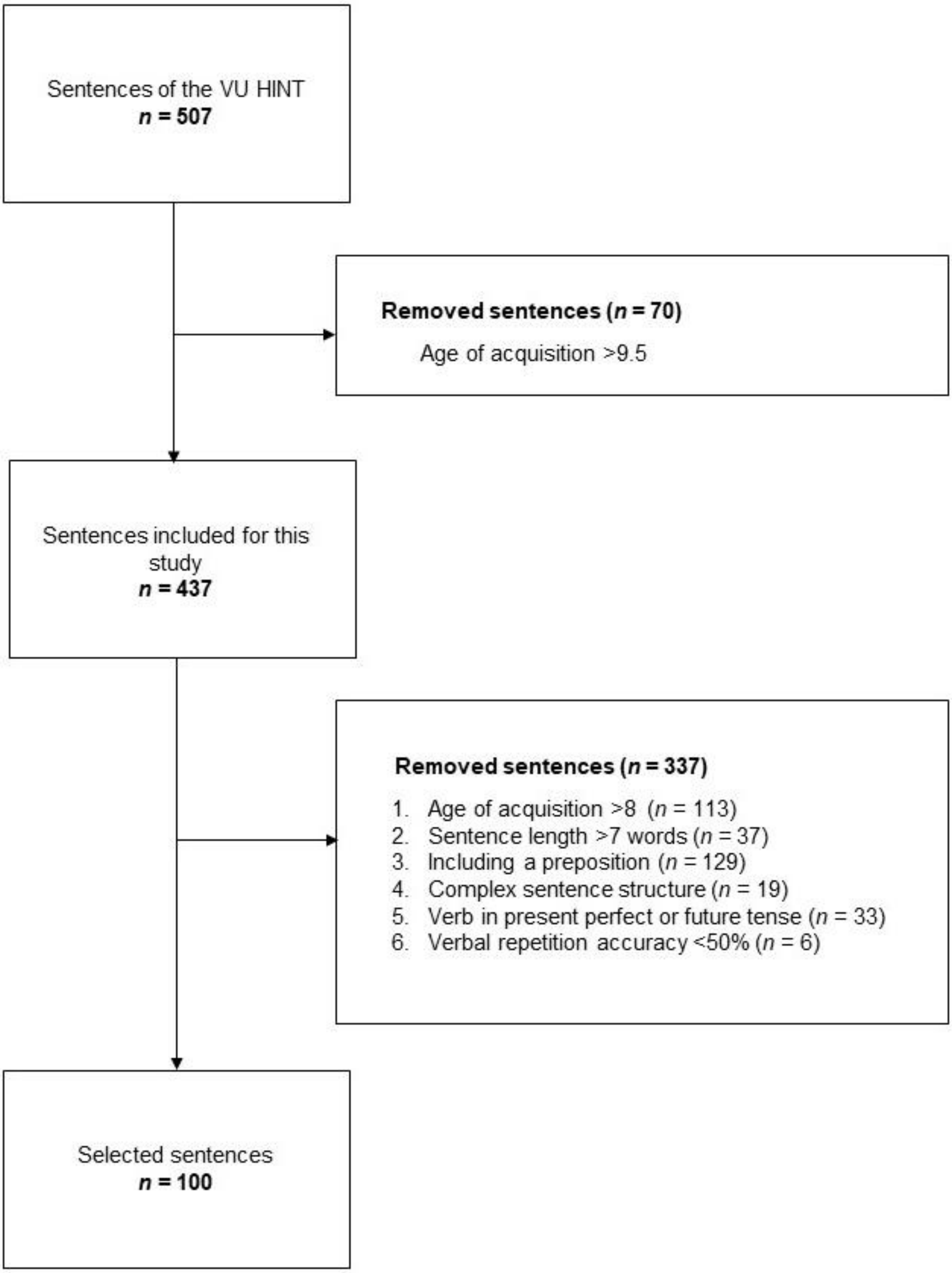

Figure 2. Flow chart of the sentence selection following the steps of the present study

APPENDIX

Sentence lists created based on a linguistic analysis of a sentence repetition task performed by 6-year-old children ($N = 40$)

Number	Sentence	AoA[a]	Sentence structure
List 1			
39	We hebben elkaar niets te zeggen	6,28	SOV
411	Ik gaf de schrijver groot gelijk	8	SOV
14	Ik heb het de hele dag koud	5,9	SOV
1	We kunnen weer even vooruit	7,53	SOV
197	De zon geeft lange schaduwen	5,96	SOV
313	Een andere keuze is er niet	7,4	SOV
230	Mijn vader kon goed vertellen	4,95	SOV
356	Vrijdag wordt hij vijftig jaar oud	6,67	OVS
160	Onze chauffeur begrijpt het niet	6,88	SOV
302	Hij kiest zijn woorden heel voorzichtig	7,09	SOV
List 2			
182	Ik wil deze stad leren kennen	5,9	SOV
15	De klapdeuren gaan vanzelf open	8	SOV
232	Ik ben de eerste die het ziet	5,15	SOV
23	Ik zag een zaklantaarn liggen	7,56	SOV
317	Ik ga snel mijn moeder bellen	6,03	SOV
60	De prijzen begonnen te dalen	7,4	SOV
326	Ze gingen altijd samen vissen	6,17	SOV
163	Meestal zit ik gewoon lekker thuis	7	OVS
507	Het is een erg gemene man	6,78	SOV
350	Het wordt tijd om te vertrekken	6,39	SOV
List 3			
370	We wonen nu dertien jaar samen	6,17	SOV
78	Ineens schiet me iets te binnen	7,83	OVS
68	De school houdt vanmiddag open dag	5,83	SOV
133	De mensen kijken hun ogen uit	7,61	SOV
143	Ik draag graag aparte kleren	7,28	SOV
401	De koningin bezoekt het feest	7,35	SOV
155	Mijn grootvader had drie zonen	5,34	SOV
497	Thuis hebben we een wereldbol	7	OVS
113	Hij maakte de brief snel open	6,78	SOV
46	De boot raakte een grote rots	6,4	SOV
List 4			
477	Je kunt niet alles mooi vinden	5,33	SOV
157	Hij maakte het pakje open	6,78	SOV
82	Zijn vader heeft zich niet laten zien	5,78	SOV
154	Ik doe vandaag alles heel langzaam	7,65	SOV
311	Er staan al veel mensen te wachten	6,06	OVS
342	We krijgen bonensoep vooraf	7,39	SOV
214	Ik ging pen en papier halen	6,15	SOV
119	Wij willen de directeur spreken	7,06	SOV
371	Hopelijk is er vanavond post	7,8	OVS
444	Ze vonden de auto te duur	6,46	SOV

List 5			
194	Mijn moeder is aan het zwemmen	5,2	SOV
28	Hij bracht de pen keurig terug	7,96	SOV
176	Haar mond staat een beetje open	5,72	SOV
388	Ze vertelt haar verhaal langzaam	7,65	SOV
11	Ik werk al heel lang met kinderen	6,06	SOV
340	Ik kon alles heel duidelijk zien	7,4	SOV
148	Haar jongste is nu zeventien	6,28	SOV
426	Ieder heeft zijn eigen verhaal	7,05	SOV
319	Plotseling krijgt hij een idee	6,71	OVS
432	Ze waren niet wakker te schudden	6,4	SOV
List 6			
33	De radio staat zachtjes aan	5,42	SOV
361	Elk jaar bezoeken ze deze streek	7,96	OVS
287	Het is een hele leuke stad	5,79	SOV
241	Hij begon zijn plan uit te leggen	7,55	SOV
383	Muziek is meer dan alleen geluid	5,96	SOV
309	Elke dinsdag vertrekt er een trein	7,33	OVS
221	De koffer is helemaal leeg	6,28	SOV
216	Iedereen heeft zijn eigen smaak	7,03	SOV
488	Haar ouders hebben een schoenwinkel	6,75	OVS
174	Hij hoorde steeds een raar geluid	6,46	SOV
List 7			
475	Mijn vrouw en ik gaan wandelen	5,39	SOV
466	Dat is al lang verleden tijd	8	SOV
338	Mijn vader zei helemaal niks	5,9	SOV
261	Het is een schitterend landschap	7,56	SOV
303	Ze zaten al een uur te wachten	6,06	SOV
359	Het is wel een aardig verhaaltje	7,3	SOV
291	Drie dagen later was het zover	6,28	OVS
43	Ze heeft natuurlijk groot gelijk	7,11	SOV
229	Hier voelen de mensen zich veilig	6,71	OVS
294	De vensterbank staat vol planten	6,54	SOV
List 8			
215	De winkel is dag en nacht open	5,34	SOV
126	Ze hadden thuis genoeg ruimte	7,99	SOV
107	Wij kennen hem nu een beetje	5,84	SOV
467	Voorzichtig raakt ze de stof aan	7,09	SOV
118	De kinderen waren alleen thuis	5,96	SOV
85	Schaatsen doen we eigenlijk nooit	7,3	OVS
228	Het begon heel hard te waaien	6,22	SOV
404	De wandeling duurt een uurtje	6,96	SOV
362	Hij moet zo rond de veertig zijn	6,89	SOV
231	Ik heb een grote boekenkast	6,69	SOV
List 9			
417	Alles is schoon en opgeruimd	6,06	SOV
277	Zulke dingen vindt hij prachtig	7,78	OVS
358	Ze zit de hele dag maar thuis	5,9	SOV
264	We reden ongeveer een uur	7,5	SOV
453	Hij heeft hele grote voeten	5,9	SOV
105	Alle vier wonen ze nog thuis	5,72	OVS
250	Ze kunnen niet zo lang stil zitten	6,33	SOV
31	Ik vond dat een heerlijk uitstapje	7,15	SOV
500	Ze begrijpen hem niet altijd	6,83	SOV
207	Dat is niet zomaar een schilderij	6,54	SOV

List 10			
208	Hij heeft zes weken vakantie	5,65	SOV
8	Daar hoeft niemand aan te twijfelen	7,67	OVS
19	Wij vonden het een mooie film	5,9	SOV
330	Ik moet er even over denken	7,53	SOV
456	Ik vind het een heel goed liedje	5,9	SOV
47	We hebben samen een afspraak	7,22	SOV
170	Bijna iedereen vond het leuk	6,39	SOV
141	Mijn familie vindt het hier prettig	6,96	SOV
305	Hij is een ware verteller	6,83	SOV
262	Hij doet zijn leren jasje aan	6,56	SOV

Note. AoA = Age of Acquisition; SOV = Subject Object Verb; OVS = Object Verb Subject