Cognitive Abilities to Explain Individual Variation in the Interpretation of Complex Sentences by Older Adults

Margreet Vogelzang (margreet.vogelzang@uni-oldenburg.de)
Institute of Dutch Studies and Cluster of Excellence "Hearing4all"
University of Oldenburg, Germany

Christiane M. Thiel (christiane.thiel@uni-oldenburg.de)
Department of Psychology and Cluster of Excellence "Hearing4all"
University of Oldenburg, Germany

Stephanie Rosemann (stephanie.rosemann@uni-oldenburg.de)
Department of Psychology and Cluster of Excellence "Hearing4all"
University of Oldenburg, Germany

Jochem W. Rieger (jochem.rieger@uni-oldenburg.de)
Department of Psychology and Cluster of Excellence "Hearing4all"
University of Oldenburg, Germany

Esther Ruigendijk (esther.ruigendijk@uni-oldenburg.de)
Institute of Dutch Studies and Cluster of Excellence "Hearing4all"
University of Oldenburg, Germany

Abstract

This paper investigates which cognitive abilities predict the interpretation of complex sentences by older adults. Participants performed a picture-selection task after hearing complex and simpler sentences, as well as a broad test battery of cognitive tests. The results show that different cognitive factors serve as predictors for the interpretation of complex sentences compared to simpler sentences. For complex sentences, verbal intelligence, cognitive flexibility, and working memory capacity are strong predictors. Our study thus shows that older adults' interpretation of sentences of varying complexity is influenced by different cognitive abilities, and stresses the need to take such individual differences into account when studying language processing.

Keywords: language processing; cognitive factors, complex sentences; syntactic structure; age; individual variation

Introduction

It is well-known in cognitive-linguistic research that syntactically complex sentences can be difficult to process (a.o. Bahlmann, Rodriguez-Fornells, Rotte, & Münte, 2007 (object-first sentences); Tun, Benichov, & Wingfield, 2010 (object relative clauses), Bader & Meng, 1999 (embedded clauses)). Especially older adults show difficulties with the processing and interpretation of complex sentences (e.g., Emery, 1985). These difficulties could partially be caused by cognitive abilities, as language processing has long been suggested to be influenced by (working) memory capacity (e.g., King & Just, 1991). In reading research, it has been found that working memory capacity and reading experience (but not vocabulary) can mediate older adults' reading times on temporarily ambiguous sentences (Payne et al., 2014). Contrary, in sentence processing in adverse listening conditions, vocabulary was found to influence older adults' performance, as was cognitive flexibility (also described as mental flexibility; McAuliffe, Gibson, Kerr, Anderson, & LaShell, 2013; Rosemann et al., 2017).

So, several cognitive factors have been suggested to influence older adults' language processing performance. Nevertheless, no consensus has been reached about which cognitive factors exactly influence complex sentence processing in older adults, and little is known about influence of cognitive abilities on the processing and interpretation of complex in comparison to simpler sentences. We therefore ran a broad test battery to examine **which cognitive abilities predict the interpretation of complex sentences by older adults**.

Object-first sentences are a common example of complex sentences. In German, canonical word order in a main clause is subject-verb-object (Zwart, 1997). However, the language allows for structurally more complex object-before-subject sentences, for example:

(1) *Den$_{ACC}$ Jungen wäscht der$_{NOM}$ Vater*
The$_{ACC}$ boy washes the$_{NOM}$ Father
'The father washes the boy'

In (1), case on the determiners indicates which noun phrase is the object (den Jungen) and which is the subject (der Vater). Although unambiguous, such object-first sentences have been found to elicit longer reading times (Hemforth, 1993) and more interpretation errors (Carroll, Uslar, Brand, & Ruigendijk, 2016) compared to subject-first sentences in German. Alternatively, an adjunct can be added at the beginning of the sentence to create a structure in which all information about the protagonists follows the verb, such as in (2).

Table 1: Examples of the four experimental conditions. Note that although the conditions use different word orders, their meaning remains the same.

Subject-object order	**Adjunct position**	**Condition**	**Example sentence**
subject-before-object	3	SVAO	Der Igel berührt am Montag den Hasen
object-before-subject	3	OVAS	Den Hasen berührt am Montag der Igel
subject-before-object	1	AVSO	Am Montag berührt der Igel den Hasen
object-before-subject	1	AVOS	Am Montag berührt den Hasen der Igel
			On Monday the$_{NOM}$ hedgehog touches the$_{ACC}$ hare

(2) *Am Montag wäscht den$_{ACC}$ Jungen der$_{NOM}$ Vater*
On Monday washes the$_{ACC}$ boy the$_{NOM}$ Father
'On Monday the father washes the boy'

In this paper, we describe an auditory sentence-processing paradigm followed by a picture-selection task. Two types of syntactic manipulations are used, namely subject-object order and adjunct position. We measured performance of our older participants on several cognitive factors that have been argued to be related to sentence comprehension: age, years of education, working memory capacity, subjective memory complaints, vocabulary, cognitive flexibility, and a composite measure of cognitive performance, which is widely used as screening for cognitive impairment.

Overall, we expect structurally more complex object-before-subject sentences to be more difficult to interpret than subject-before-object sentences (in line with Carroll et al., 2016). We additionally expect adjunct-first sentences to be more difficult to interpret than adjunct-third sentences, as adjunct-first sentences also violate canonical word order (i.e. verb-subject-object rather than subject-verb-object). Moreover, we expect considerable variation in both the interpretation of complex sentences (cf. Vos, Gunter, Schriefers, & Friederici, 2001) and the performance on the cognitive tasks. We expect the performance on several cognitive factors to influence the interpretation of complex sentences, such as age (Rosemann et al., 2017), working memory (Payne et al., 2014; Vos et al., 2001), and vocabulary and cognitive flexibility (McAuliffe et al., 2013; Rosemann et al., 2017). It will then be investigated which of these cognitive tasks best accounts for the interpretation of complex sentences by older adults.

Methods

Participants

20 older adults (age 51-70, mean age 60; 15 females) participated in the study. All participants had age-normal hearing as tested before the experiment and normal or corrected-to-normal vision. The participants were all monolingual native speakers of German and reported no language impairments and no psychiatric or neurological issues. The ethics committee of the University of Oldenburg approved of the study (reference number Drs. 28/2017) and written informed consent was obtained from all participants.

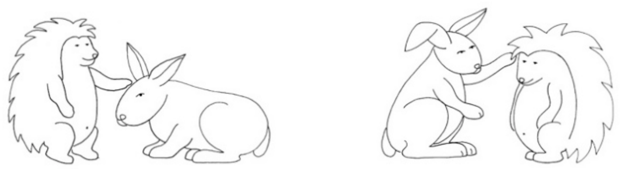

Figure 1: Example pictures corresponding to the sentences in Table 1.

Main Linguistic Task

The linguistic task used auditorily presented German sentences based on the OLACS corpus (Uslar et al., 2013), each followed by two pictures for a picture-selection task. Each sentence consisted of a Subject (S), a transitive Verb (V), an Adjunct (A), and an Object (O). Four different sentence conditions were used (see Table 1): SVAO sentences with canonical word order, OVAS sentences in which the object is placed sentence-initially, adjunct-initial AVSO sentences, in which the verb is placed before its arguments, and adjunct-initial AVOS sentences, in which the subject-object order is additionally manipulated. The task was performed in an fMRI scanner, which inherently creates noise. Therefore, a pre-task was used to control for the loudness of presentation of the stimuli[1].

After each sentence, two pictures (modified from Wendt, Brand, & Kollmeier, 2014) were displayed. These presented both characters mentioned in the sentence performing the mentioned action (the adjunct was not displayed in the pictures, see example pictures corresponding to the sentences in Table 1 in Figure 1). Participants could indicate the picture that best fit the sentence with a response box: the left button for the left picture and the right button for the right picture. The location of the target picture on the screen (left or right) was counterbalanced across trials.

[1] The loudness was adjusted for each participant individually to 80% intelligibility with the Oldenburg Matrix Sentence Test (OLSA; Wagener, Kühnel, & Kollmeier, 1999). The average adjusted loudness of stimuli presentation was 71.5dB (SD = 6.8).

The experiment used 24 sentences per condition, so 96 trials in total. The trials were distributed over two sessions. Two lists with pseudo-randomized presentation orders were created.

Cognitive Tasks

In addition, several cognitive tests were applied: A standard backwards *Digit Span* task (Tewes, 1991) as a measure of simple working memory capacity, the Comprehensive *Trail Making* test (Reynolds, 2002) as a measure of cognitive flexibility, a German *Vocabulary* test called 'Wortschatztest' (Schmidt & Metzler, 1992) as an index of verbal intelligence, the Montreal Cognitive Assessment (*MoCA*; Nasreddine et al., 2005)[2] as a concise screening tool for mild cognitive impairment, and a German version of the self-reported age-related *Memory Assessment* Clinics Questionnaire (Crook, Feher, & Larrabee, 1992) as an index of subjective memory complaints. Finally, participants' *Age* and years of formal *Education* (from primary school up to high school/university/PhD) were assessed through a questionnaire. Of the Trail Making task, following Rosemann et al. (2017), only trail 1 (connecting numbers in order: 1-2-3...) and trail 5 (connecting numbers and letters alternatingly in order: 1-A-2-B-3-C...) were used and participants' score was calculated as the difference in completion time between trail 5 and trail 1.

Procedure

Participants were tested individually at the University of Oldenburg. First, participants were asked to fill out a questionnaire asking for age and years of education, as well as the self-reported Memory Assessment questionnaire. Second, pure-tone audiogram measurements were taken in a soundproof booth. Then, the Trail Making, MoCA, and Digit Span tasks were conducted. After two practice rounds of 6 sentences with the same conditions as in the main experiment, the main linguistic experiment started. The pre-task controlling for the loudness of the stimuli and the main linguistic experiment took place in an MRI scanner; the fMRI results will be published in a separate paper. Participants used headphones during all tasks in the MRI scanner. After the first session of the main experiment, participants came out of the scanner and performed the Vocabulary task, before going back into the scanner for the second session of the experiment and some structural scans. The total testing time was about 3 hours.

Analyses and Results

One participant's Trail Making task was not performed in line with the experiment protocol and therefore excluded from the analysis (the participant took off their glasses halfway through the task). All other participants completed all the tasks.

[2] Approval for the use of this test was obtained from the MoCA Clinic & Institute.

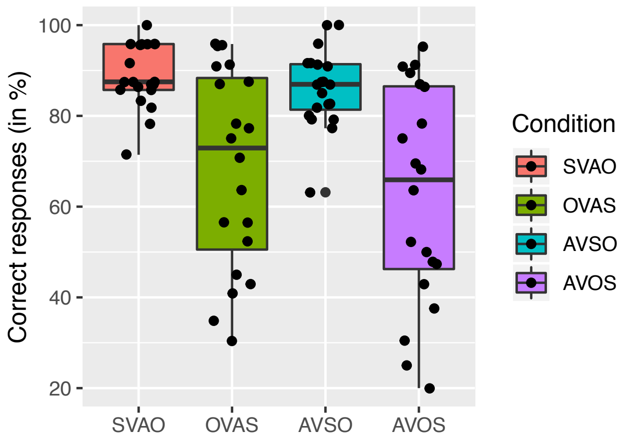

Figure 2: Percentages of correct responses and distribution of these responses on the linguistic task per condition. Each dot indicates the mean score of a participant on a condition. Overall means per condition are SVAO: 89%, OVAS: 69%, AVSO: 86%, and AVOS: 63%.

Main Linguistic Task

We first analyzed the correct responses per condition on the picture-selection task (Figure 2) with generalized linear mixed-effects models (lme4, Bates, Maechler, Bolker, & Walker, 2014). Based on the experimental design, the fixed effects of subject-object order and adjunct position as well as their interaction were included in the model. Based on model comparisons, random intercepts for subjects and items, as well as random slopes for subject-object order per subject and for subject-object order and adjunct position per item were included as random factors in the model. Subject-before-object and adjunct-third were used as the baseline.

The model results (Table 2) show lower performance on object-before-subject sentences (OVAS and AVOS) than on subject-before-object sentences (SVAO and AVSO). This confirms our expectation that object-before-subject sentences are more complex and more difficult to interpret than subject-before-object sentences. No significant effect of adjunct position or interaction between subject-object order and adjunct position was found.

Table 2: Statistical comparison of response accuracies in the linguistic task (corrected for multiple comparisons).

Factor	***ß***	***z*-score**	***p*-value**
Subject-object order	-1.38	-4.32	< 0.001
Adjunct position	-0.30	-2.09	0.07
Subject-object order* Adjunct position	-0.04	-0.16	0.87

As can be seen in Figure 2, on both of the more complex object-before-subject conditions, OVAS and AVOS, participants show very large individual variation; on the subject-before-object conditions participants show less variation. We will now look at whether this individual variation can be explained by the participants' cognitive abilities.

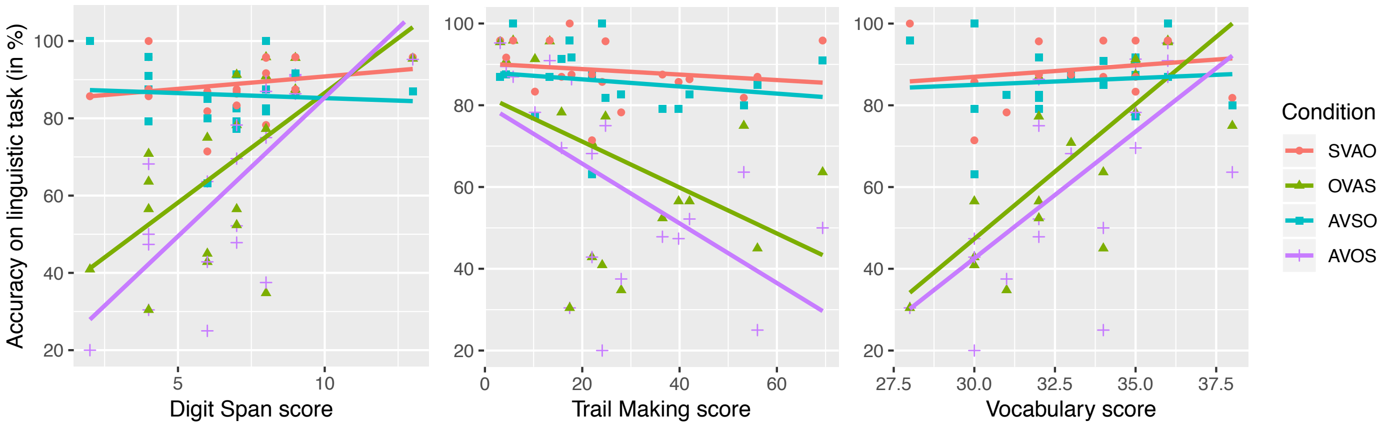

Figure 3: The relation between the performance on the linguistic task and on the Digit Span task (left), indicating working memory capacity, on the Trail Making task (middle), indicating cognitive flexibility, and on the Vocabulary task (right), indicating verbal intelligence.

Cognitive Tasks

We will perform two sets of analyses investigating the relation between the tested cognitive factors and performance on the linguistic task. First, we will examine the influence of each single cognitive factor by running generalized linear mixed-effect models with each factor separately. This analysis will show which cognitive factors influence the processing of simple and complex sentences. Additionally, we will examine the influence of the cognitive factors in combination with each other on the linguistic task by means of an inference tree. This will show which combination of cognitive factors has the strongest predictive power when it comes to interpreting sentences of different complexities and which are thus most useful to take into account when investigating (complex) sentence processing.

Linear mixed-effects models (lme4, Bates, Maechler, Bolker, & Walker, 2014) were developed for each cognitive task separately. The same model was used as for the analysis of the linguistic task, including the fixed effects of subject-object order and adjunct position as well as their interaction, but this time adding the cognitive tasks as co-variates. All significant effects are reported in the text, but only the most interesting effects will be elaborated upon. The results show, after correcting for multiple comparisons, no effects of *MoCA*, *Age*, and *Education* on the responses on the linguistic task (all p's > 0.05). A main effect of *Memory Assessment* was found ($\beta = 0.08$; $z = 2.89$; $p < 0.01$), indicating that people with more memory complaints actually performed better on the linguistic task.

For *Digit Span*, a significant main effect ($\beta = 0.22$; $z = 3.38$; $p < 0.001$) as well as an interaction with subject-object order ($\beta = 0.38$; $z = 4.08$; $p < 0.001$) were found. In Figure 3 (left panel), the relation between participants' scores on the Digit Span task and on the linguistic task per condition is plotted. The figure shows that participants with higher scores on the Digit Span task (indicating better working memory capacity) perform much better on the object-before-subject conditions than participants with lower scores. Conversely, no clear effect of working memory capacity is observed in the subject-before-object order, suggesting that processing the object-before-subject sentences requires additional working memory capacity compared to subject-before-object word order.

For *Trail Making*, also an interaction with subject-object order ($\beta = -0.04$; $z = -2.86$; $p < 0.001$) was found. Figure 3 (middle panel) shows the relation between participants' scores on the Trail Making task and on the linguistic task per condition. A higher trail making score reflects worse performance on the Trail Making test. Hence, subjects with worse scores on the Trail Making task perform worse on the linguistic task with object-before-subject sentences.

Finally, for *Vocabulary,* a significant main effect ($\beta = 0.21$; $z = 3.59$; $p < 0.001$) as well as an interaction with subject-object order ($\beta = 0.33$; $z = 4.04$; $p < 0.001$) were found. In Figure 3 (right panel) the relation between participants' scores on the Vocabulary task and on the linguistic task per condition is shown, making it clear that participants with higher verbal intelligence performed better on the object-before-subject conditions than participants with lower verbal intelligence.

All three interactions occur with object-before-subject sentences, indicating that interpretation of complex object-before-subject but not simpler subject-before-object sentences is influenced by these factors. Thus, it appears that processing more complex sentences draws on additional cognitive resources, whereas processing the simpler subject-before-object sentences requires less resources, presumably because they do not require additional analysis.

Best Predictors

One could argue that performance on Digit Span, Trail Making, and Vocabulary could be intercorrelated, and therefore these tasks may all explain the same effects in the data. Therefore, we will now investigate which cognitive factors *in combination* form the best predictors for the interpretation of sentences with different complexities and thus which are most useful to take into account in future investigations. Because investigating all factors within one mixed-effects model creates difficulties due to the large amount of variables, we favor conditional

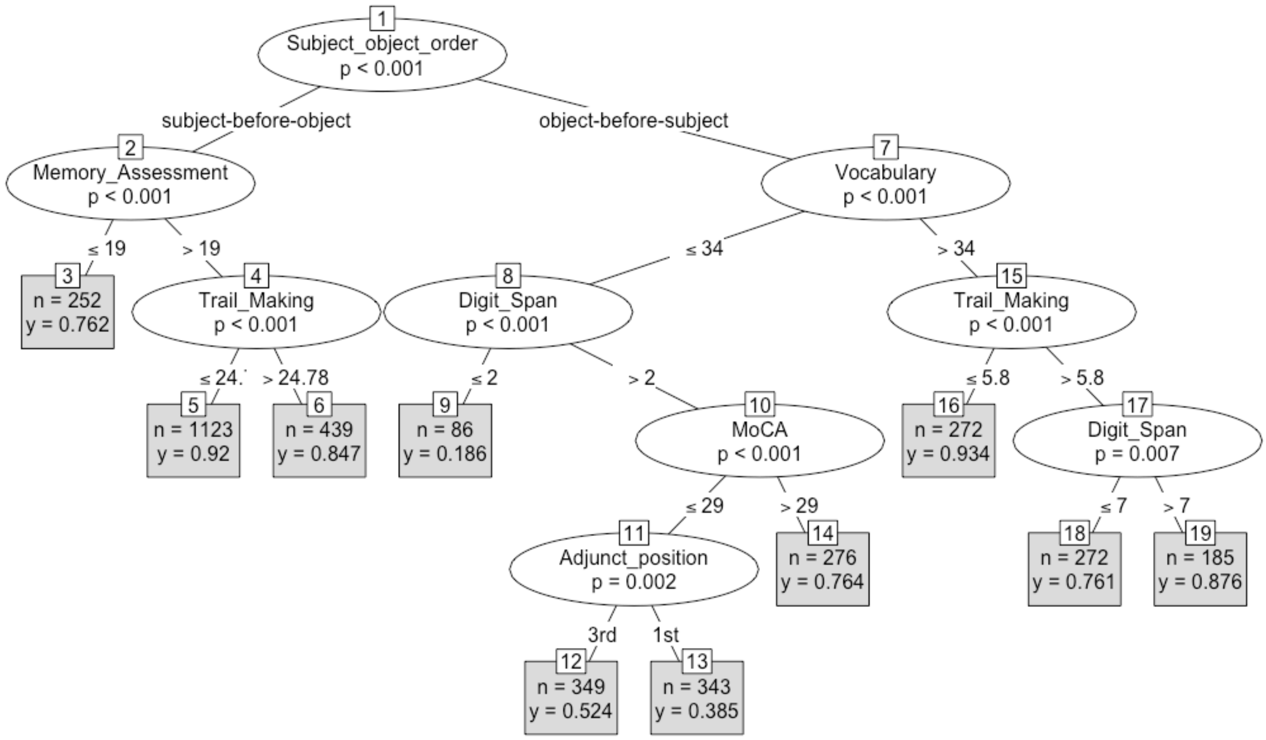

Figure 4: A conditional inference tree showing which of the tested predictors (*Subject-object order, Adjunct position, Digit Span, Trail Making, Vocabulary, MoCA, Memory Assessment, Age,* and *Education*) are the best predictors of response accuracy. The gray boxes indicate the number of trials (n) and proportion of correct responses (y) per branch.

inference trees (ctree from the party package, Hothorn, Hornik, & Zeileis, 2006), which are a type of decision tree. These provide non-parametric tree-based regression models and can handle large numbers of variables.

This method uses a significance test procedure in order to select the variables (cognitive factors) that best predict the response accuracy on the linguistic task. Notably, our two linguistic conditions, subject-object order and adjunct position, are entered as possible predictor variables as well. Using this method, we can investigate which variables most strongly predict the accuracy on our picture-selection task; stronger predictors are higher up in the tree. Variables that are not significant predictors do not occur in the tree at all. Besides showing which variables are predictors of response accuracy, the tree also shows how well individual performance can be predicted given these variables. The results of the analysis are shown in Figure 4 (including *p*-values per variable). Each branch of the tree represents the trials in certain conditions for participants with certain cognitive scores.

The results show that subject-object order is the strongest predictor for the performance on the picture-selection task, as it is highest up in the tree. For subject-before-object sentences, subjective *Memory Assessment* is the strongest predictor, followed by *Trail Making* score lower in the tree. In the gray boxes, the number of trials (n) and the mean proportion of correct responses (y), are displayed for each branch. For example, the 252 trials in the leftmost branch, in the simpler subject-before-object conditions responded to by people with a Memory Assessment score equal to or smaller than 19, were answered correctly 76.2% of the time.

For more complex object-before-subject sentences, *Vocabulary* is the strongest predictor of performance on the linguistic task, followed by *Digit Span* and *MoCA* for participants with a lower Vocabulary score, and *Trail Making* and *Digit Span* for participants with a higher Vocabulary score. Notably, MoCA is a significant predictor only for people with a lower Vocabulary score and a higher digit span score; this explains why there was no main effect of MoCA in the linear mixed-effects models. Interestingly, for participants with a lower Vocabulary score, a higher Digit Span score and a lower MoCA score, adjunct position is a significant predictor of performance on the linguistic task, whereas for other participants no influence of adjunct position is found.

Importantly, Vocabulary, Digit Span, Trail Making (and MoCA) all appear in the decision tree, indicating that they explain different parts of the data, i.e. they are complementary, and therefore that taking all these tests into account is useful when examining complex sentence interpretation.

Discussion

In this paper, we aimed to identify cognitive abilities that can predict the interpretation of complex sentences by older adults. We will focus on the most clear and convincing results here. As predicted, complex object-before-subject sentences were more difficult for older adults to interpret than subject-before-object sentences. Contrary to our predictions, adjunct-first sentences were only more difficult to interpret than adjunct-third sentences for part of the participants. Regarding cognitive abilities, we found that working memory capacity (*Digit*

Span), cognitive flexibility (*Trail Making*), and verbal intelligence (*Vocabulary*) are not only correlated with complex sentence processing as single factors, but also when they are combined. The analysis of all factors combined showed an additional effect of general cognitive performance (*MoCA*) for participants with lower verbal intelligence. Interestingly, age and years of education did not influence participants' performance (compare Stine-Morrow, Ryan, & Leonard, 2000).

The strong predictive power of verbal intelligence is striking. This does not reflect familiarity with the words in the linguistic task, since all conditions, simple and complex, used the same words. Rather, it could indicate that people with a broader and deeper vocabulary are able to access and process words more easily, thereby freeing up capacity for higher-level processing (in line with evidence from speech recognition, McAuliffe et al., 2013, but contra Ramscar, Hendrix, Shaoul, Milin, & Baayen, 2014). Moreover, verbal intelligence could be related to general intelligence or language (e.g., reading) experience (cf. Payne et al., 2014), which may increase familiarity with and aid the processing of complex structures.

Overall, our linguistic picture-selection task was quite challenging, which is reflected in the large amount of individual variation. Some participants showed around chance performance on object-before-subject sentences, suggesting that (1) their working memory capacity was insufficient to keep and manipulate all information in memory (cf. Just & Carpenter, 1992), (2) their verbal intelligence was insufficient to access their lexicon efficiently (cf. McAuliffe et al., 2013), (3) their cognitive flexibility was insufficient to process sentences with non-typical word order, and/or (4) their general cognitive performance was insufficient to process complex sentences. Conversely, simpler subject-before-object sentences do not seem to require high working memory capacity or verbal intelligence. This dissociation is in line with the idea that processing syntactically simpler constructions loads general cognitive resources less than processing syntactically more complex constructions.

One could argue that all cognitive factors that were found to affect complex sentence processing actually all belong to one latent factor. Ramscar et al. (2014), for example, suggest that a larger and more experienced lexicon has more complex representations, which require more demanding searches to be accessed, causing delays and decreased performance on linguistic and other psychometric tests. Our analyses show, however, that the different cognitive factors have a *complementary* effect; they explain different parts of the data, suggesting that the tasks tap into different underlying mechanisms.

Conclusion

Our study identified several cognitive factors that can serve as predictors of the interpretation of complex sentences by older adults, which differ from the factors that predict the interpretation of simpler sentences. The investigation thus highlights the complementary influence of different cognitive abilities on language processing, and emphasizes the need to consider not only working memory capacity, but also factors such as verbal intelligence and cognitive flexibility when investigating complex sentence processing.

Acknowledgements

This work was funded by the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation) under Germany's Excellence Strategy – EXC 2177/1 - Project ID 390895286. We would like to thank Jan Michalsky for his help with recording the stimuli and Rebecca Carroll for her help with recording and preparing the stimuli.

References

Bader, M., & Meng, M. (1999). Subject-object ambiguities in German embedded clauses: An across-the-board comparison. *Journal of Psycholinguistic Research*, *28*(2), 121–143. http://doi.org/10.1023/A:1023206208142

Bahlmann, J., Rodriguez-Fornells, A., Rotte, M., & Münte, T. F. (2007). An fMRI study of canonical and noncanonical word order in German. *Human Brain Mapping*, *28*(10), 940–949. http://doi.org/10.1002/hbm.20318

Bates, D. M., Maechler, M., Bolker, B., & Walker, S. (2014). Package 'lme4.'

Carroll, R., Uslar, V., Brand, T., & Ruigendijk, E. (2016). Processing Mechanisms in Hearing-Impaired Listeners: Evidence from reaction times and Sentence Interpretation. *Ear and Hearing*, *37*(6), e391–e401. http://doi.org/10.1097/AUD.0000000000000339

Crook, T. H., Feher, E. P., & Larrabee, G. J. (1992). Assessment of Memory Complaint in Age-Associated Memory Impairment: The MAC-Q. *International Psychogeriatrics*, *4*(2), 165–176. http://doi.org/10.1017/S1041610292000991

Emery, O. B. (1985). Language and aging. *Experimental Aging Research*, *11*(1), 3–60. http://doi.org/10.1080/03610738508259280

Hemforth, B. (1993). *Kognitives Parsing: Repräsentation und Verarbeitung sprachlichen Wissens*. Sankt Augustin, Germany: Infix Verlag.

Hothorn, T., Hornik, K., & Zeileis, A. (2006). Unbiased Recursive Partitioning: A Conditional Inference Framework. *Journal of Computational and Graphical Statistics*, *15*(3), 651–674. http://doi.org/10.1198/106186006X133933

Just, M. A., & Carpenter, P. A. (1992). A capacity theory of comprehension: Individual differences in working memory. *Psychological Review*, *99*(1), 122–149. http://doi.org/10.1037/0033-295X.99.1.122

King, J., & Just, M. A. (1991). Individual differences in syntactic processing: The role of working memory. *Journal of Memory and Language*, *30*(5), 580–602. http://doi.org/10.1016/0749-596X(91)90027-H

McAuliffe, M. J., Gibson, E. M. R., Kerr, S. E., Anderson, T., & LaShell, P. J. (2013). Vocabulary influences older and younger listeners' processing of dysarthric speech. *The Journal of the Acoustical Society of America*, *134*(2), 1358–1368. http://doi.org/10.1121/1.4812764

Nasreddine, Z. S., Phillips, N. A., Bédirian, V., Charbonneau, S., Whitehead, V., Collin, I., … Chertkow, H. (2005). The Montreal Cognitive Assessment, MoCA: A brief screening tool for mild cognitive impairment. *Journal of the American Geriatrics Society*, *53*(4), 695–699. http://doi.org/10.1111/j.1532-5415.2005.53221.x

Payne, B. R., Grison, S., Gao, X., Christianson, K., Morrow, D. G., & Stine-Morrow, E. A. L. (2014). Aging and individual differences in binding during sentence understanding: evidence from temporary and global syntactic attachment ambiguities. *Cognition*, *130*(2), 157–73. http://doi.org/10.1016/j.cognition.2013.10.005

Ramscar, M., Hendrix, P., Shaoul, C., Milin, P., & Baayen, H. (2014). The Myth of Cognitive Decline: Non-Linear Dynamics of Lifelong Learning. *Topics in Cognitive Science*, *6*(1), 5–42. http://doi.org/10.1111/tops.12078

Reynolds, C. R. (2002). *Comprehensive TrailMaking Test*. Austin, TX: Pro-Ed.

Rosemann, S., Gießing, C., Özyurt, J., Carroll, R., Puschmann, S., & Thiel, C. M. (2017). The Contribution of Cognitive Factors to Individual Differences in Understanding Noise-Vocoded Speech in Young and Older Adults. *Frontiers in Human Neuroscience*, *11*(294), 1–13. http://doi.org/10.3389/fnhum.2017.00294

Schmidt, K.-H., & Metzler, P. (1992). *Wortschatztest [MultipleChoice Word Test]*. Weinheim: Beltz Test GmbH.

Stine-Morrow, E. A. L., Ryan, S., & Leonard, J. S. (2000). Age Differences in On-Line Syntactic Processing. *Experimental Aging Research*, *26*(4), 315–322. http://doi.org/10.1080/036107300750015714

Tewes, U. (1991). *Hamburg-Wechsler-Intelligenztest für Erwachsene — Revision 1991 (HAWIE-R)*. Bern: Huber.

Tun, P. A., Benichov, J., & Wingfield, A. (2010). Response latencies in auditory sentence comprehension: Effects of linguistic versus perceptual challenge. *Psychology and Aging*, *25*(3), 730–735. http://doi.org/10.1037/a0019300

Uslar, V. N., Carroll, R., Hanke, M., Hamann, C., Ruigendijk, E., Brand, T., & Kollmeier, B. (2013). Development and evaluation of a linguistically and audiologically controlled sentence intelligibility test. *The Journal of the Acoustical Society of America*, *134*(4), 3039–3056. http://doi.org/10.1121/1.4818760

Vos, S. H., Gunter, T. C., Schriefers, H., & Friederici, A. D. (2001). Syntactic parsing and working memory: The effects of syntactic complexity, reading span, and concurrent load. *Language and Cognitive Processes*, *16*(1), 65–103. http://doi.org/10.1080/01690960042000085

Wagener, K. C., Kühnel, V., & Kollmeier, B. (1999). Entwicklung und evaluation eines satztests in deutscher sprache I: design des oldenburger satztests [Development and evaluation of a German sentence test I: design of the oldenburg oldenburg sentence test]. *Zeitschrift Für Audiologie*, *38*, 4–15.

Wendt, D., Brand, T., & Kollmeier, B. (2014). An eye-tracking paradigm for analyzing the processing time of sentences with different linguistic complexities. *PLoS ONE*, *9*(6). http://doi.org/10.1371/journal.pone.0100186

Zwart, C. J. W. (1997). The Germanic SOV Languages and the Universal Base Hypothesis. In L. Haegeman (Ed.), *The New Comparative Syntax*. London/New York: Longman.