Individual differences in language ability: Quantifying the relationships between linguistic experience, general cognitive skills and linguistic processing skills

Florian Hintz (Max Planck Institute for Psycholinguistics), Cesko C. Voeten (Leiden University), Christina Isakoglou (Radboud University), James M. McQueen (Radboud University), Antje S. Meyer (Max Planck Institute for Psycholinguistics)

Most people acquire their native language effortlessly, yet individuals differ greatly in how they use it. Language ability strongly influences people's functioning in society and is an important predictor of professional success. Although the question 'what makes someone a good language user?' has intrigued scholars for a long time, little is known about the principal dimensions of language skills. Most studies adopted qualitative approaches (i.e., asking 'is X involved in Y?') and focused on the involvement of just one variable in linguistic processing skills (e.g., working memory in sentence comprehension). Such approaches ignore the contribution of other potentially relevant variables and do not allow for a quantification of the relationships between multiple potentially relevant variables. Therefore, the conclusions that may be drawn about the principal dimensions of language skills are limited.

In the present study, we took a first step towards a comprehensive characterization of individual differences in language skills. We tested 112 young adults (aged between 18 and 29 years) in a lab-based setting on a recently developed behavioral test battery (Hintz et al., 2020). The battery included 33 tests designed to assess nine key constructs reflecting language skills and skills assumed to be involved in linguistic processing: Word production, Word comprehension, Sentence production, Sentence comprehension, Linguistic experience, Non-verbal processing speed, Working memory, Inhibition, and Non-verbal intelligence. Except for non-verbal intelligence, we included multiple tests per psychological construct to address task impurity.

Using principal component analysis (PCA, number of expected components was unconstrained) we first assessed how strongly each individual test loaded on the construct it was assumed to measure. The results showed that the majority of tests loaded strongly on their respective construct, none of the PCAs yielded more than one component (Table 1, for an overview). Then one score for each of the nine constructs was extracted for each participant. These scores were submitted to a correlation analysis. The correlations among the nine scores are presented in the heatmap in Figure 1 (Panel A). Finally, the correlation matrix from Panel A was converted into a distance matrix and then submitted to a hierarchical clustering analysis. Panel B plots the outcome of this analysis as a dendogram. Correlation and hierarchical clustering analyses revealed strong correlation/similarity between non-verbal processing speed and language comprehension, especially word comprehension. Moreover, we observed a strong correlation between linguistic experience and language production, especially word production. While word-level and sentence-level skills *within* a domain were related, the hierarchical clustering analysis yielded separate clusters for comprehension and production. In line with previous research, working memory, non-verbal intelligence, and to a lesser extent inhibition clustered together. These general cognitive skills correlated weakly to moderately with linguistic processing skills and formed a separate cluster in the hierarchical clustering analysis.

In sum, the present study constitutes a first step towards a comprehensive, quantitative characterization of individual differences in language skills. Our results extend previous research by demonstrating a strong influence of general cognitive skills (i.e., processing speed) on comprehension and of linguistic experience on production. The present data further suggest that production and comprehension skills are less related than one might have thought.

We are currently testing a larger sample of participants with diverse educational backgrounds using versions of the tests presented here that can be run via the internet. Moreover, next to charting the variability in language skills at the behavioral level, we will investigate its neurobiological and genetic underpinnings.

Table 1: The table presents the loadings of the individual tests on the construct they were assumed to measure as well as the amount of variance explained, established using PCA.

Word production (42% variance explained)	**Word comprehension** (43% variance explained)	**Sentence production** (61% variance explained)	**Sentence comprehension** (55% variance explained)
Picture naming -*.53*	Non-word monitoring noise -*.44*	Phrase generation *.78*	Gender cue activation *.91*
Antonym production -*.54*	Word monitoring noise -*.27*	Sentence generation *.78*	Verb semantics activation *.91*
Verbal fluency (Sem.) -*.71*	Meaning monitoring noise -*.42*		Monitoring noise *.02*
Verbal fluency (Phon.) -*.72*	Rhyme judgment -*.85*		
Maximal speech rate -*.48*	Auditory lexical decision -*.85*		
One minute test -*.76*	Semantic categorization -*.83*		
Klepel test -*.72*			
Linguistic experience (58% variance explained)	**Non-verbal processing speed** (53% variance explained)	**Working memory** (48% variance explained)	**Inhibition** (56% variance explained)
Peabody test *.84*	Auditory simple RT *.74*	Digit span (forward) *.80*	Eriksen flanker task *.75*
Spelling test *.75*	Auditory choice RT *.85*	Digit span (backward) *.77*	Antisaccade task *.75*
ART *.82*	Letter comparison *.47*	Corsi block (forward) *.61*	
Idiom recognition *.54*	Visual simple RT *.73*	Corsi block (backward) *.56*	
Prescriptive grammar *.83*	Visual choice RT *.82*		

Note: Non-verbal intelligence is not listed as it was measured using a single test.

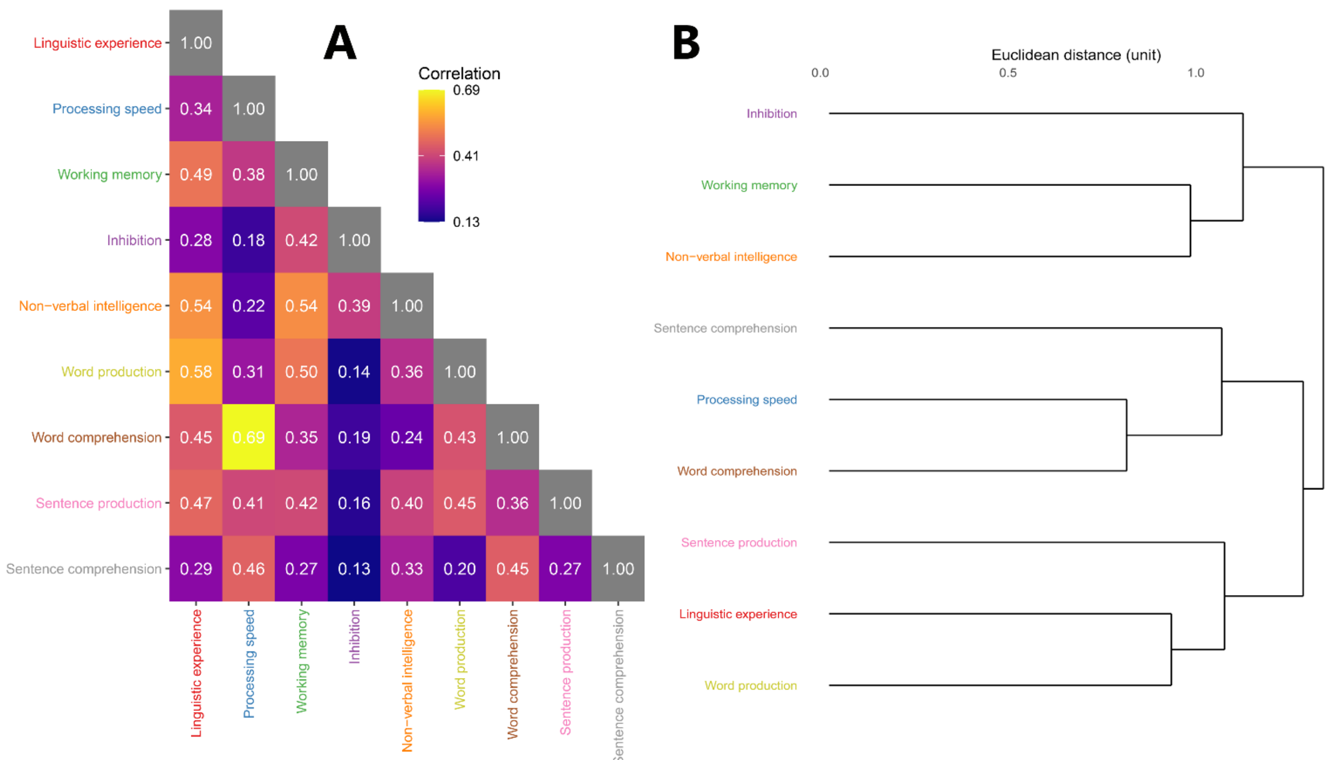

Figure 1: Panel A presents a correlation matrix based on the nine PCA-derived scores. The scale ranges from the weakest to the strongest correlation between any two scores in the set. Panel B presents a dendogram as outcome of the hierarchical clustering analysis, based on the correlations in Panel A. In the dendogram, scores that are similar (i.e., closer) cluster together.

Reference

Hintz, F., Dijkhuis, M., Van 't Hoff, V., McQueen, J. M., & Meyer, A. S. (2020). A behavioural dataset for studying individual differences in language skills. *Scientific Data, 7*: 429.