Resting State Power Predicts Cognitive Control and Language Abilities

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In language tasks, individuals not only use language-specific processes but also domain-general skills [1,2]. Both cognitive and linguistic task performance have been related to brain functioning, in particular to power (i.e. the number of neurons discharging synchronously) in certain frequency bands as measured by EEG. High average theta (4 to 8 Hz) is associated with poor performance on memory tasks, and high alpha (8 to 12 Hz) with good performance on attention tasks [3]. Similarly, beta frequency (12 to 30 Hz) modulations have been linked to aspects of linguistic processing [4]. Even power measured at rest has been shown to predict later task performance: alpha power is related to general intelligence [5], beta power predicts the level reached in a second language training program [6], and theta power is related to sentence comprehension abilities [7]. This suggests that stable network properties at rest can determine performance outcomes. The present study assessed pivotal linguistic and language learning skills and investigated whether the relationship between domain-general skills and linguistic skills found behaviorally was driven by shared brain network functioning at rest.

Dutch young adults (N = 52, data collection ongoing) performed a battery of tasks aimed to test language abilities and general cognitive abilities. See Table 1 for all tasks and the resulting individual differences measures. In addition, five minutes of eyes-closed resting state EEG (64ch) was recorded and power analyses were performed. Using Fast Fourier Transform, the power spectrum was calculated for 2-sec epochs, which was log-transformed, and then averaged across all epochs. For each participant and channel, power was calculated for the frequency range 4 to 30 Hz. Correlations between each of the individual differences measures and the power values were tested using cluster-based permutations [8], identifying significant clusters in both spatial and spectral dimensions.

Five significant clusters were found (Table 2). Differences in verbal fluency and scores on the Peabody Vocabulary test were related to variation in the beta frequency range: lower resting state beta power was related to an increase in both the retrieval (fluency) and storage (vocabulary) of lexical items. The two effects were spatially distinct (Figure 1). None of the other linguistic tasks correlated with oscillatory activity at rest. For three cognitive skills – working memory, executive control, and processing speed – better performance was related to higher power, albeit in different frequency ranges. Amongst these five behavioral tasks, only executive control and vocabulary size correlated significantly (r = -.35, p = .01). These results show that stable brain functioning is not only related to cognitive skills, but also to linguistic skills. The different relationships between power and skill were present not only in different frequency ranges and distinct spatial locations but in opposite directions for language and cognition, suggesting these are supported by different oscillatory networks.

[1] Huettig & Janse, 2016, Lang Cogn Neurosci, 31:1; [2] Shao et al, 2012, Q J Exp Psychol, 65:10; [3] Klimesch, 1999, Brain Res Rev, 29:2; [4] Weiss & Mueller, 2012, Front Psychol, 3:201; [5] Doppelmayr et al., 2002, Intelligence, 30:3; [6] Prat et al., 2016. Brain Lang, 157, [7] Beese et al., 2017, Sci Rep, 7:1; [8] Maris & Oostenveld, 2007, J Neurosci Methods, 164:1.

Table 1. The behavioral task battery

Skill	Task	Measure
Word comprehension	Lexical Decision	Average RT
Word production	Picture Naming	Average RT
Lexical access	Verbal Fluency	Number of items retrieved
Vocabulary size	Peabody	Percentile score
Word learning	Novel word learning	RTs for correct items
Grammar learning	Artificial grammar learning	Accuracy
Intelligence	Raven's 20 min	Total number of correct items
Working memory	Digit span	Score forward + backward
Alerting	Attention Network Test	Double cue RT – no cue RT
Orienting	Attention Network Test	Spatial cue RT – center cue RT
Executive control	Attention Network Test	Congruent RT – incongruent RT
Processing Speed	Simple-RT, Choice-RT, Letter comparison	Factor score from average RTs for each task

Table 2. Correlations between linguistic/cognitive skills and EEG power

Skill	Correlation	Frequency	P-value
Word comprehension	n.s.		
Word production	n.s.		
Lexical access	negative	11 to 30 Hz	0.022
Vocabulary size	negative	13 to 30 Hz	0.002
Word learning	n.s.		
Grammar learning	n.s.		
Intelligence	n.s.		
Working memory	positive	10 to 14 Hz	0.044
Alerting	n.s.		
Orienting	n.s.		
Executive control	positive	4 to 30 Hz	0.015
Processing Speed	negative	15 to 24 Hz	0.049

Figure 1. Topography of effects