

Variation in how cognitive control modulates sentence processing

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Prior research suggests that cognitive control assists the comprehension of garden-path sentences that create conflict between interpretations. However, doubts remain about how cognitive control could influence a seemingly specialized and temporally tuned function like sentence processing. Our hypothesis tries to reconcile the two perspectives by proposing that cognitive control might influence (1) the online processing of sentences that require the integration of multiple conflicting cues but not other complex structures; (2) the offline decision processes related to choosing an interpretation and doing the experimental task. We also hypothesized that these effects could be modulated by individual differences in cognitive control. We found suggestive correlational evidence in six persons with aphasia: patients who showed large Stroop effects also showed slowed-down processing of sentences with multiple conflicting cues. We looked for additional causal evidence by testing healthy younger adults in a “conflict modulation” paradigm.

We measured word-by-word self-paced reading times and comprehension accuracy for three types of sentences in a web-based study (N=78 healthy adults aged 18-35 years). Within each type, we had congruent (sentence matches prior language and world experience) and incongruent (sentence violates expectations) conditions (see Table 1). Sentences were interleaved with Stroop trials. A given sentence could follow a congruent (e.g., “blue” in blue font) or incongruent (e.g., “orange” in blue font) Stroop trial. A 2x2 conflict modulation design (Stroop congruence x Sentence congruence) tested whether a previous Stroop trial affected the processing of a subsequent sentence. Trial order was pseudorandomized and condition assignment was counterbalanced across lists. No participant read both the congruent and incongruent versions of the same sentence. On a separate day, participants completed cognitive control (Stroop, AXCP, Flanker) and working memory (reading, operation, and backwards digit spans) tasks.

Exploratory factor analysis confirmed the separability of individuals’ cognitive control and working memory abilities (see Figure 1). Cognitive control predicted (1) online conflict modulation at specific disambiguation points for syntax-semantics (*by*: $t=-2.2$, $p=.03$; *the*: $t=2.1$, $p=.04$) but not other sentence types; and (2) offline comprehension accuracy for syntax-semantics ($t=-1.8$, $p=.07$) and phrase-attachment ($t=-4.5$, $p<.001$) but not relative clause sentences. In contrast, working memory predicted (3) offline comprehension accuracy for relative clause sentences ($t=3.2$, $p=.002$).

Together, the results show that the effect of cognitive control on online and offline sentence comprehension is modulated by both the type of sentence/conflict and individual differences in cognitive control ability. We suggest that the theoretical controversy regarding the conflict modulation effect could be resolved by better understanding variability. Clinically, this perspective has ramifications for characterizing and treating different individuals with aphasia.

Table 1. Example sentences, comprehension questions, and answer options

Type	Condition	Sentence	Question
Syntax-Semantics	Congruent	During the filming, the actor was directed by the creative producer.	Did someone instruct the actor? Options: Yes/No. Correct answer is Yes.
	Incongruent	During the first rehearsal, the conductor was directed by the creative musician.	Did the conductor instruct someone? Options: Yes/No. Correct answer is No.
Phrase Attachment	Congruent	Working at the valet stand, Colin said put the car that's in the entrance into the parking lot and drive slowly.	Where did the car end up? Options: Entrance/Parking Lot/Other. Correct answer is Parking Lot.
	Incongruent	Working at the valet stand, Colin said put the car in the entrance into the parking lot and drive slowly.	
Relative Clause	Congruent	In the research institute, the technician who contacted the lab manager was analyzing the biological samples.	Did someone contact the technician? Options: Yes/No. Correct answer is No.
	Incongruent	In the research institute, the technician who the lab manager contacted was analyzing the biological samples.	Did someone contact the technician? Options: Yes/No. Correct answer is Yes.

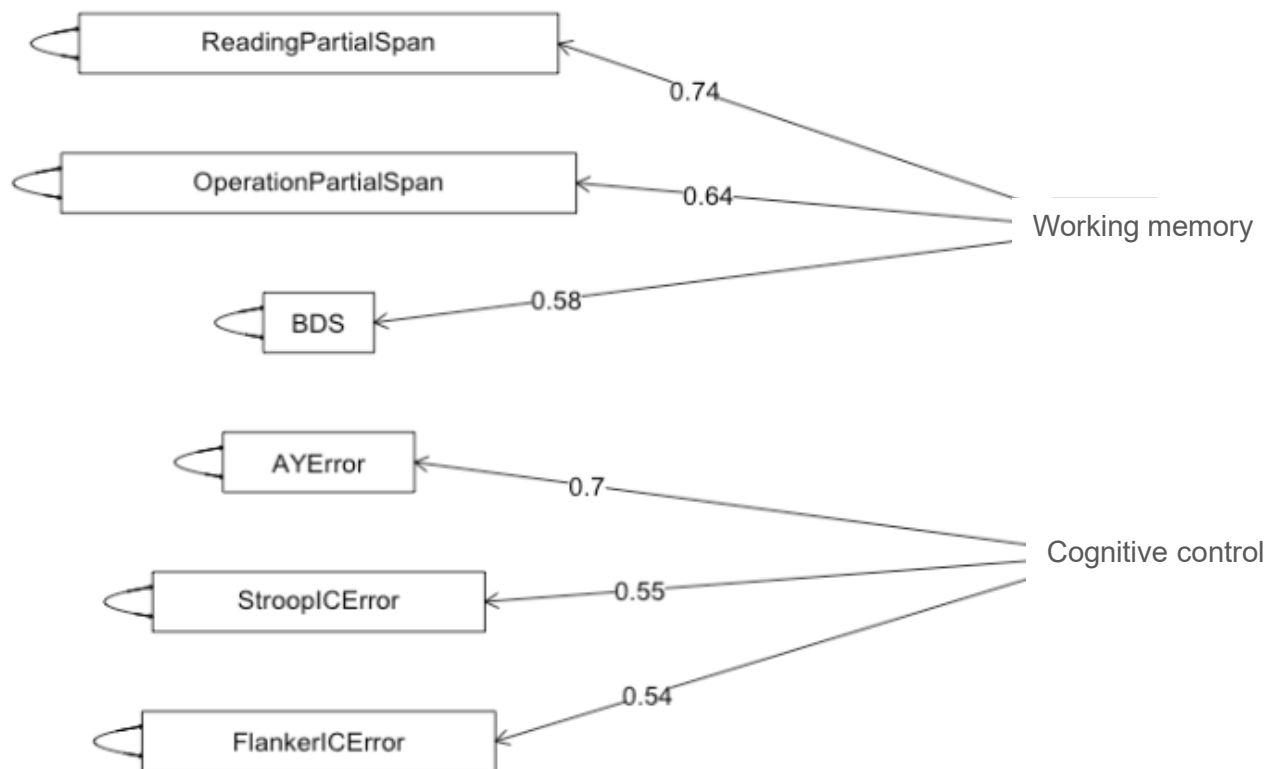


Figure1. Path diagram from exploratory factor analysis fitted using a Maximum Likelihood with a Varimax rotation. Measures: Reading, Operation and Backwards Digit spans (BDS); Errors in the incongruent trials of AXCPT, Stroop, and Flanker tasks.