Cognitive Control Modulates Sentences Comprehension in Individuals with Aphasia

Introduction: Aphasia is commonly described as a language disorder. However, persons with aphasia (PWA) often experience deficits in cognitive control—the mental capacity required to detect and resolve conflicts. These deficits can pose challenges in interpreting sentences containing conflicting information. For example, for the sentence like "The cop was handcuffed by the robber," in which the syntactic information contradicts semantics, a listener might arrive at the reverse interpretation (i.e., cop handcuffing robber). Modulations in cognitive control can influence the interpretation of such sentences in neurotypical adults, often referred to as “conflict adaptation” (Thothathiri et al., 2018). Using a conflict adaptation paradigm with interleaved auditory Stroop and sentence-to-picture matching tasks, we investigated whether modulating cognitive control enhances the comprehension of sentences with conflict in PWA with mild (Study 1) and moderate (Study 2) comprehension deficits.

Methods: In Study 1, four individuals (P1, P2, P3, P4; 1 female) with mild aphasia participated in four conflict adaptation sessions, with American English as the tested language. Each session included interleaved auditory Stroop and sentence-to-picture matching trials. On Stroop trials, participants identified the gender of the speaker (male or female) saying “boy” or “girl”. On sentence trials, participants chose the picture (out of four) that best matched the heard sentence. Sentences were syntactically correct, but varied in their semantic plausibility (plausible, e.g., “The robber was handcuffed by the cop,” vs. implausible, e.g., “The cop was handcuffed by the robber”). Auditory Stroop congruency was crossed with sentence congruency, resulting in four conditions: congruent Stroop followed by congruent sentence (CC), congruent Stroop followed by incongruent sentence (CI), incongruent Stroop followed by congruent sentence (IC), and incongruent Stroop followed by incongruent sentence (II). We hypothesized that incongruent Stroop would modulate the comprehension of incongruent, but not congruent, sentences, as only incongruent sentences involve conflict and require cognitive control. We analyzed reaction times (RTs; note that accuracy was at ceiling) and participants’ eye movements to target pictures during incongruent sentences using mixed-effects models. To assess if cognitive modulations impact accuracy performance, we recruited two other individuals with moderate aphasia (P5, P6; 1 female) for Study 2. The participants completed an adjusted version of the conflict adaptation experiment twice (i.e., eight sessions in total), followed by a separate eye-tracking sentence-to-picture matching task. All participants underwent background testing (see Table 1), and their cognitive control abilities were measured with a separate Stroop task.

Results: In Study 1, P4 exhibited conflict adaptation with faster RTs for incongruent active sentences ($\beta = -0.11$, $SE = 0.05$, $t = -2.17$, $p = .04$) and more rapid growth in fixations to target pictures for incongruent passive sentences ($\beta = 3.03$, $SE = 0.68$, $z = 4.48$, $p < .001$) in the II condition compared to the CI condition (Fig. 1A and B). Cognitive control additionally modulated active sentence processing in P1, with an initial dip in fixations to target pictures followed by their rapid increase in the II condition compared to CI ($\beta = 1.46$, $SE = 0.52$, $z = 2.81$, $p < .01$; Fig. 1B). In Study 2, none of the effects were significant. However, we calculated chance levels using a binomial test with alpha .05 and 33% chance probability. P5 was above chance in the II (mean accuracy = 42%) but at chance in the CI (mean accuracy = 27%) condition for passive sentences, suggesting conflict adaptation (Fig. 1C). P6 showed no accuracy differences between conditions (mean accuracy = 45% for both). Eye-tracking data revealed distinct sentence processing strategies: P5 over-relied on semantic cues, fixating on more plausible but incorrect pictures ($\beta = -1.56$, $SE = 0.56$, $z = -2.76$, $p = .006$), while P6 fixated more often on the correct pictures ($\beta = 0.92$, $SE = 0.25$, $z = 3.63$, $p < .001$).

Conclusions: Cognitive control can modulate sentence comprehension in individuals with aphasia, but the effects vary across individuals. Eye tracking demonstrated differences in sentence processing, which might relate to who can or cannot benefit from conflict adaptation. These results bear on theoretical questions about when cognitive control is relevant for sentence comprehension (and when it is not), and potential clinical applications for improving language outcomes in aphasia using conflict adaptation.

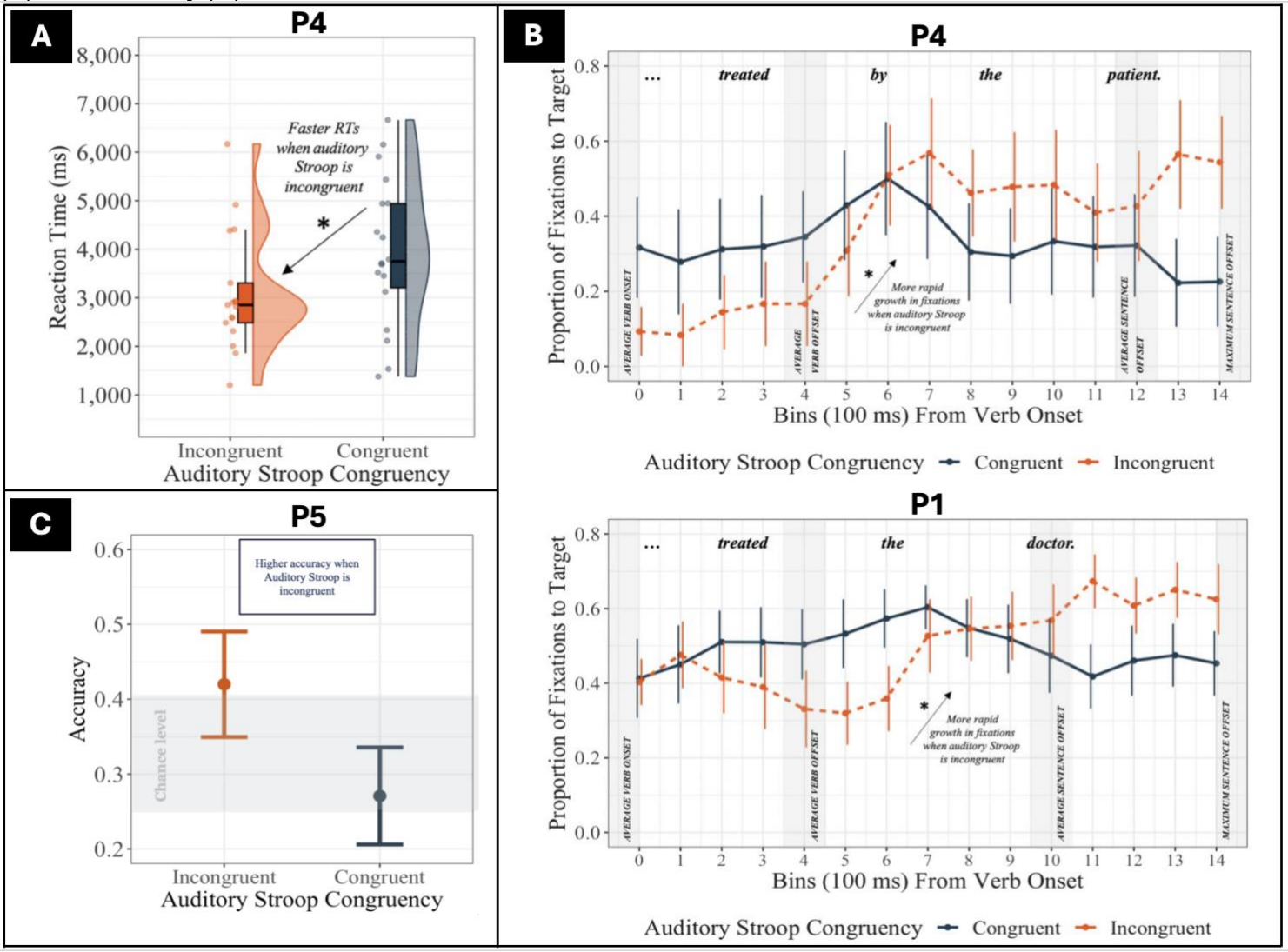
Figures and Tables

Table 1. Background testing

ID	WAB-Comprehension	WAB-AQ	Philadelphia Comprehension Battery	
			Lexical	Syntactic
P1	10	79.6	100%	93.33%
P2	9.85	96.3	100%	90%
P3	10	95.2	93.3%	93.3%
P4	10	95.8	100%	100%
P5	8.65	88.5	83.33%	43.33%
P6	8.5	65.4	80%	50%

Note: WAB: Western Aphasia Battery-Revised (Kertesz, 2007)

Figure 1. Cognitive control modulation effects for different participants as indicated by RTs (A), eye movements (B), and accuracy (C).



Note: Panel B: Shaded areas represent critical verb onsets/offsets and sentence offsets. The example sentences are “The doctor was treated by the patient” (top) and “The patient treated the doctor” (bottom).

References

1. Kertesz, A. (2007). Western Aphasia Battery–Revised. The Psychological Corporation.
2. Thothathiri, M., Asaro, C. T., Hsu, N. S., & Novick, J. M. (2018). Who did what? A causal role for cognitive control in thematic role assignment during sentence comprehension. Cognition, 178, 162–177. https://doi.org/10.1016/j.cognition.2018.05.014