Improving Garden-Path Recovery Through Cognitive Control Training

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BACKGROUND & HYPOTHESES

The Role of Cognitive Control in Sentence Processing:
- Psycholinguistic studies emphasize the importance of cognitive control (also known as executive function, EF) when readers/listeners must override early, incorrect interpretations when new input conflicts with developing analyses.
- Extreme populations, including young children and patients with damage to left prefrontal regions, have difficulty revising initial misinterpretations of sentences (garden-path recovery failure).
- This failure is believed to be associated with these groups’ putative difficulty resolving interference on non-semantic cognitive control tasks.

Research Questions: Can cognitive control be trained? Will garden-path recovery benefit?
- Recent research demonstrates that cognitive control can be improved through extensive practice. The findings suggest that training gains generalize beyond well-learned tasks—i.e., transfer across domains to new measures that also rely on cognitive control.
- Here we ask: Can healthy readers’ ability to revise misinterpretations be improved through cognitive control training?

Predictions:
- Improving domain-general cognitive control functions through training should benefit recovery from misinterpretation. This may be reflected in readers’ overall interpretations of sentence meaning and also in real-time eye movement measures marking the launch of recovery efforts.
- Individual training gains may predict the degree of garden-path recovery.

METHOD

2 Groups of Healthy Adults: Trained vs. Untrained Controls

Pretest (Eye-Tracking during Reading)
- No Contact (N = 22)
- Training (N = 22)
- 20 hours general cognitive control training

Posttest (Eye-Tracking during Reading)
- Linguistic Materials: Reflective / Transitive Ambiguity
  - While the thief hid the jewelry sparkled brightly (Ambiguous)
  - The jewelry sparkled brightly while the thief hid the item (Unambiguous)
- Performance-adaptive EF training tasks were given. All involved the regulation of mental activity. For example: N-Back Task, which targeted interference resolution

RESULTS

Training Gains and Selective Changes in Offline Comprehension

Trainees improve steadily throughout training on well-practiced training tasks:

Transfer

Trainees show selective improvement: Comprehension improves only for ambiguous items (requiring cognitive control). Trainees outperform untrained controls at posttest.

Individuals benefit least from training show more predictable ambiguity effects:

Summary & Conclusions

- Trainees’ (but not untrained controls’) accuracy improved to comprehension questions probing for revision failure. There were no changes, crucially, for unambiguous items.
- Eye-movements that reflect improved real-time reanalysis are shown for trainees only, in conflict regions only.
- N-back training gains predict comprehension improvements for sentences requiring ambiguity resolution.
- Domain-general cognitive control training transfers to untaught skills measuring sentence processing, specifically in cases requiring controlled revision (i.e., garden-path recovery)
- N-back was the only training task requiring subjects to practice interference resolution (through overriding familiarity of interference lure); thus, it was the only training task to reliably predict improvements in interpretation revision, a task that employs common interference resolution mechanisms.
- Garden-path recovery is a plastic cognitive skill amenable to change through EF training.

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**ABSTRACT**

To understand how individuals comprehend language, it is important to consider how non-linguistic cognitive functions contribute to interpretation processes. Cognitive control refers to the regulation of mental activity to support flexible behavior. During parsing, one important cognitive control function involves readers/listeners ability to override early syntactic analyses in view of new, conflicting evidence [1]. For example, patients with damage to left prefrontal cortex (PFC) and young children commonly fail to revise early parsing decisions [2,3] – a profile that has been tied to their difficulty performing a range of cognitive control tasks outside the syntactic domain [4,5].

We explore whether intensive training on cognitive control tasks improves garden-path recovery in healthy adults. A 20-hour training regimen was designed to increase cognitive control abilities, motivated by other research demonstrating that performance improves on well-practiced task(s), and that such improvements transfer to untrained cognitive control measures [6,7]. Our training battery included working-memory tasks involving interference resolution, and therefore heightened cognitive control demands [7]. Notably, training did not include sentence reading of any kind. Training-task difficulty adjusted to individual levels, keeping participants on the threshold of their best performance.

Forty-six adults were assigned to training or no-contact control groups and completed pre/post assessments (Assessments-1 and -2), including a reading task using the reflexive/transitive ambiguity (“While Anna dressed the baby cried loudly”) and unambiguous baselines (“The baby cried loudly while Anna dressed”). Eye-movements were recorded. Comprehension questions probed for full reanalysis (“Did Anna dress herself?”), where incorrect “no” responses gauged lingering effects of misinterpretation [8].

Assessment-1 revealed a 31% ambiguity effect for comprehension errors (Ambiguous_errors vs. Unambiguous_errors; p<.01) and no group differences (p>.60). At Assessment-2, trainees’ errors decreased reliably (30% to 17%; p<.05) whereas controls’ did not (33% to 27%; p>.10). Corroborating this pattern, eye-movement changes emerged in trainees only, reflecting training-related adjustments in real-time revision: upon encountering disambiguating evidence (“cried”), trainees but not controls spent less time at Assessment-2 re-reading earlier regions versus Assessment-1 (p<.05). No reading-time differences were observed for unambiguous sentences, suggesting that training selectively alleviated processing difficulty initiated by new evidence that conflicted with early parsing commitments, i.e., situations requiring controlled reanalysis. Eye-movement patterns from a second garden-path-recovery assessment using a different ambiguity (DO/SC ambiguity) revealed similar selective changes for the training but not the control group. Specifically, changes emerged in disambiguating regions of DO-Ambiguous items only, again suggesting that training acutely affected individuals’ ability to resolve conflicting evidence [1].

Finally, individual gains on the training tasks predicted individual levels of improvement in accuracy to lingering garden-path questions: performance at participants’ first training session did not predict ambiguity effects at either Assessment (p’s>.22), but better performance at the final training session reliably predicted smaller post-training ambiguity effects (r=-.49; p<.05).

These results provide new insight into how domain-general functions contribute to language processing. Future work should examine training-induced activation changes in PFC regions common to syntactic and non-syntactic cognitive-control [9], and compare training to active comparison groups to isolate the cognitive control mechanisms being trained.

**REFERENCES**


