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.[1-3]
- Extreme populations, including young children[4] and patients with damage to left prefrontal regions[2], 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-syntactic cognitive control tasks.[5-6]

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--they transfer across domains to new measures that also rely on cognitive control.[7-9]
- 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

3-6 Weeks

Pretest (Eye-Tracking during Reading)

No Contact (N = 22)

Training (N = 21) — *20 hours general cognitive control training*

Posttest (Eye-Tracking during Reading)

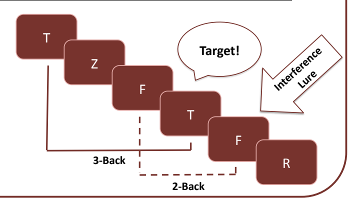
Linguistic Materials: Reflexive / Transitive Ambiguity[10]

While the thief hid the jewelry sparkled brightly. *(Ambiguous)*
vs.
The jewelry sparkled brightly while the thief hid. (Unambiguous)

Comprehension questions probed for lingering effects of misinterpretation:
Did the thief hide himself?
("No" response indexes failure to revise)

8 performance-adaptive EF training tasks were given. All involved the regulation of mental activity. For example: N-Back Task, which targeted interference resolution

3-Back Condition: *Respond if the current item matches the item presented 3 previously.*

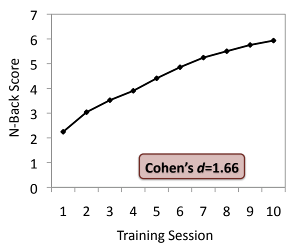


Results

Error Bars = ±1 SEM; *p < 0.05

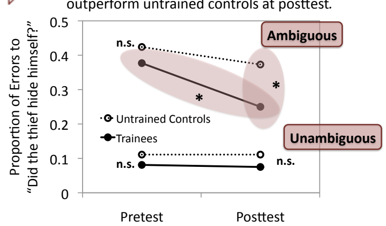
Training Gains and Selective Changes in Offline Comprehension

Trainees improve steadily throughout training on well-practiced training tasks

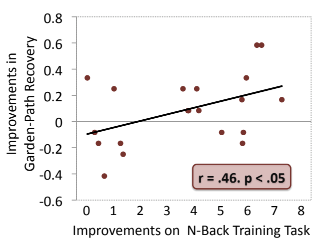


Transfer

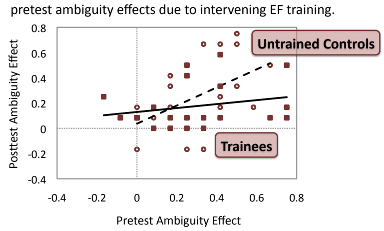
Trainees show selective improvement: Comprehension improves ***only*** for ambiguous items (requiring cognitive control). Trainees outperform untrained controls at posttest.



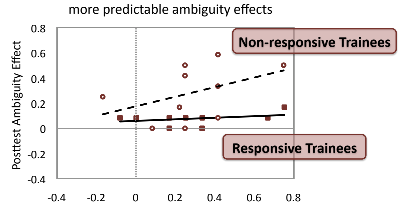
Training improvements predict gains in garden-path recovery



Untrained participants' ambiguity effects are stable over time (pretest reliably predicts posttest). Trainees' posttest ambiguity effects cannot be predicted by pretest ambiguity effects due to intervening EF training.



Individuals benefiting ***least*** from training show more predictable ambiguity effects



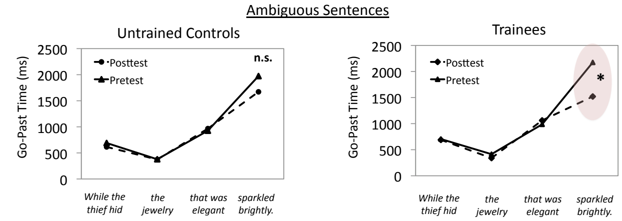
*Participants' mean performance at their first n-back session, crucially, did not predict ambiguity effects at pre or posttest. Better performance at their **final** training session predicted smaller posttest ambiguity effects. This pattern holds when examining just target and lure performance.*

Transfer: Selective Changes in Real-time Processing

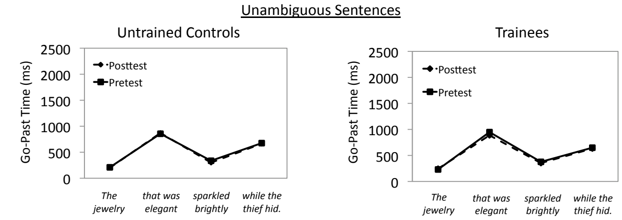
Eye Movements: Go-Past Time
(How long it takes a reader to go past a particular region)

Trainees spend less time at posttest re-reading when disambiguating (conflicting) evidence is encountered! No change for unambiguous items, as expected, or in non-conflict regions of ambiguous items. Untrained controls do not show this pattern.

Ambiguous Sentences



Unambiguous Sentences



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 untrained tasks 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 lures[8]); 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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IMPROVING GARDEN-PATH RECOVERY THROUGH COGNITIVE CONTROL TRAINING

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 <u>transfer</u> 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 similarly 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 <u>final</u> 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.

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