Preserved cumulative semantic interference despite amnesia

a single case study demonstrates the implicit nature of interference in both continuous and blocked cyclic picture naming

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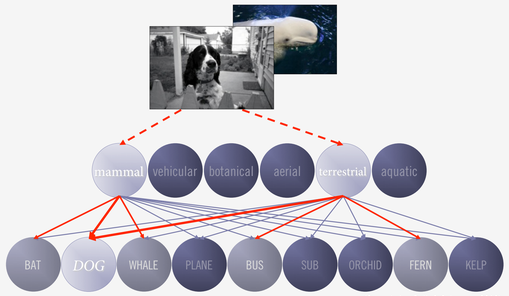
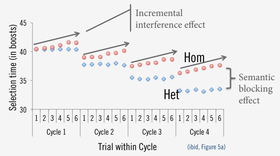
What is the role of implicit learning in language production? How can we distinguish its contributions from those of explicit memory? Current theoretical work is converging on a role for implicit incremental learning in continually adapting and maintaining the language production system (e.g. syntax: Chang et all, 2006; phonotactics: Dell et al, 2000; words: Oppenheim et al, 2010). But because language use is memorable, it is difficult to disentangle the contributions of implicit learning from explicit memory in the typical undergraduate population. Studies of patients with hippocampal damage – and resulting explicit memory impairments – can therefore provide a unique window onto the processes that underlie purported effects of implicit learning in language (e.g. Ferreira et al, 2008).

One current battleground for the implicit/explicit debate concerns the cumulative semantic interference effects that have been repeatedly and robustly observed in both continuous (e.g. Howard et al, 2006) and blocked-cyclic picture naming (Damian et al., 2001). For instance, one prominent account (Oppenheim et al, 2010; illustrated below) proposes that interference in both paradigms emerges from implicit learning in the mappings from semantic features to words: naming a 'dog' strengthens the connection to 'dog' from a shared 'mammal' feature, and weakens the connections to 'bat' and 'whale'.



(Oppenheim, Dell, & Schwartz, 2010)

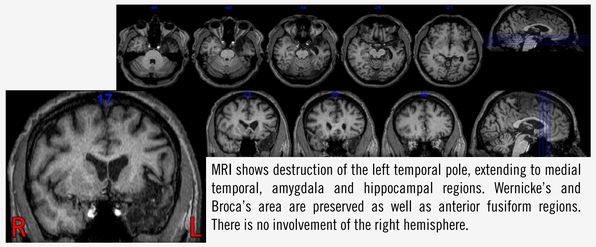


But much recent work has sought to distinguish the interference that emerges from these paradigms (e.g. Belke & Stielow, 2013; de Zubicaray et al, 2014; Llorens et al, 2014), considering different loci and mechanisms as well as differential contributions from memory processes. For instance, one recent study (de Zubicaray et al, 2014) interpreted perfusion changes in the left hippocampus as evidence that the interference in blocked cyclic naming uniquely derives from explicit memory processing. Another current proposal holds that short-term memory for a stimulus set may *reduce* the accumulation of interference in the cyclic paradigm (Belke & Stielow, 2013).

Here, we evaluate the possible role of explicit memory by testing a patient with left hippocampal damage and memory impairments on both continuous and blocked-cyclic picture-naming tasks, after ruling out semantic refractory disorders. To the extent that either creation or limitation of cumulative semantic interference normally requires explicit lexical memory, his results should diverge from the canonical patterns.

Case report

- WRP is a 52-year-old right-handed male educated to degree level. In 2011, he suddenly developed a fever accompanied by a severe headache. Upon hospitalisation, he was diagnosed with HSV. His MRI, below, shows left hemisphere lesions to his hippocampus, amygdala, and anterior to medial temporal lobe.



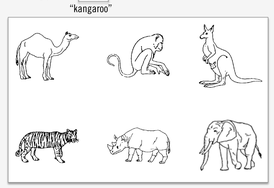
MRI shows destruction of the left temporal pole, extending to medial temporal, amygdala and hippocampal regions. Wernicke's and Broca's area are preserved as well as anterior fusiform regions. There is no involvement of the right hemisphere.

- Neuropsychological assessment: WRP presented with fluent speech with normal syntactic and phonological processes, but mild surface dyslexia/dysgraphia and word naming difficulties. ACE-R and MMSE revealed no dementia and his visual and auditory processing skills were preserved. Though our previous work has suggested category-specific semantic deficits (e.g. Roberts et al, 2014), control-like CCT performance (57/64 vs. $\mu_{control}$=58.95) suggests relatively intact semantic processing.
- Memory impairments were evident in CVLT-II (recognition: d'_2=-3; recall: z=-3), BCoS (recall$_{immediate}$: 6/15; recall$_{delayed}$: 5/15), and MOCA (recall$_{delayed}$: 0/5), and additional tests have shown poor memory for paired associates and novel words, thus setting the stage for the present study.

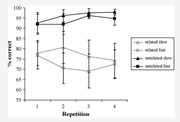
Here we rule out semantic refractory disorders:

(cf e.g. Warrington & Crutch, 2004; Jefferies et al, 2007; Gardner et al, 2012)

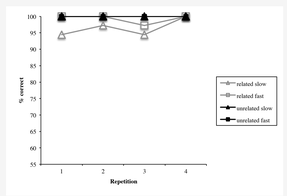
Word-picture matching probe: "kangaroo"



Word-picture matching is near ceiling, unimpaired by short ISIs

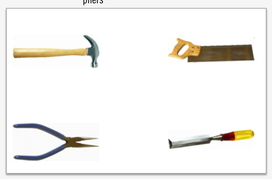


This comparison figure from Jefferies et al, 2007, shows word-picture matching accuracy from aphasia patients with semantic refractory disorders in the same experiment

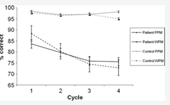


WRP showed near-ceiling accuracy for word-picture matching. While errors were more numerous for related blocks, they were actually less frequent at fast ISIs, ruling out a semantic refractory disorder

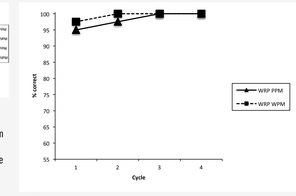
Word-picture matching probe: "pliers" Picture-picture matching probe:



Picture-picture matching is similarly control-like



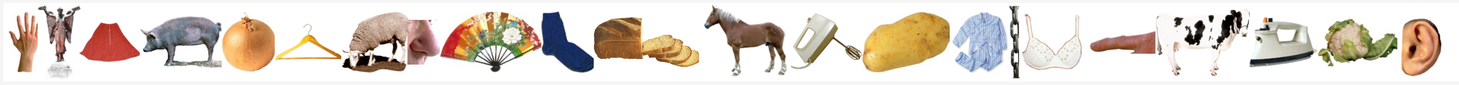
This comparison figure from Gardner et al, 2012, shows word-picture and picture-picture matching accuracies from controls and patients with multimodal semantic refractory disorders in the same experiment.



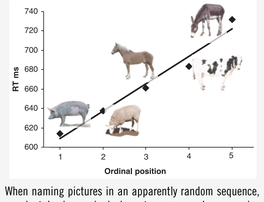
WRP showed near-ceiling accuracy for both word-picture matching and picture-picture matching, better resembling healthy controls than Gardner et al's refractory disorder group.

Thus, left hippocampal damage and demonstrably impaired explicit memory, combined with fully intact linguistic processing and only mildly impaired semantics, can help us distinguish implicit from explicit processes in two widely used "implicit word learning" paradigms

Continuous picture naming

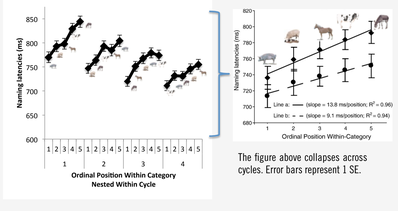


Cumulative semantic interference in continuous picture naming does not require explicit memory (e.g. Howard et al, 2006; Navarrete et al, 2010)

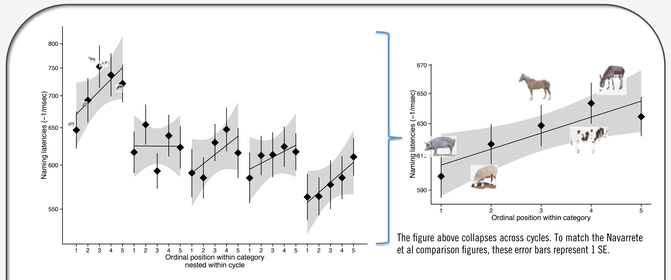


When naming pictures in an apparently random sequence, people take increasingly long to name each successive exemplar of a single sematic category. This comparison figure, from Howard et al, 2006, shows unblocked naming latencies from 24 unimpaired participants, naming many of the same pictures in Australian English. Their procedure, however, used only a single pass through one large block.

Navarette et al's, 2010, modification increased power a bit by essentially repeating Howard et al's experiment several times within a single session. The comparison figures below, show unblocked naming latencies from their 20 unimpaired students, naming the same pictures/sequences in Italian. Naming latencies slowed by 13.8ms/position, dropping to 9.1ms/position after adjusting for general within-cycle slowing.



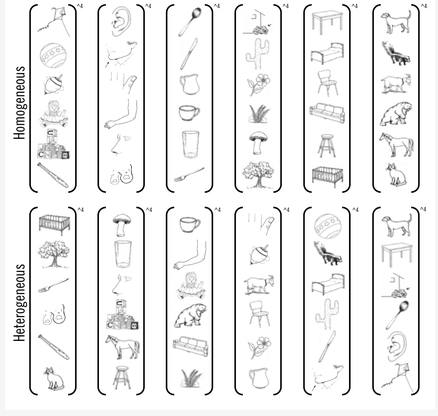
The figure above collapses across cycles. Error bars represent 1 SE.



The figure above collapses across cycles. To match the Navarrete et al comparison figures, these error bars represent 1 SE.

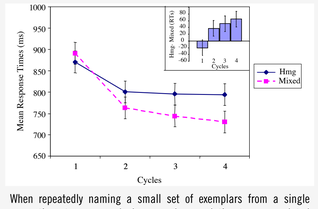
With 90.3% accuracy (vs. 91.3% for Navarrete et al's unimpaired) across four five-cycle sessions (1200 critical trials), WRP's naming latencies show similar semantic interference accumulating within each large, unblocked cycle (8.5ms/position, SE= 2.9, p=.007; interaction with cycle: p=.67; via maximal lmer of inverse-transformed correct RTs, after adjusting for general within-cycle slowing).

Blocked-cyclic picture naming



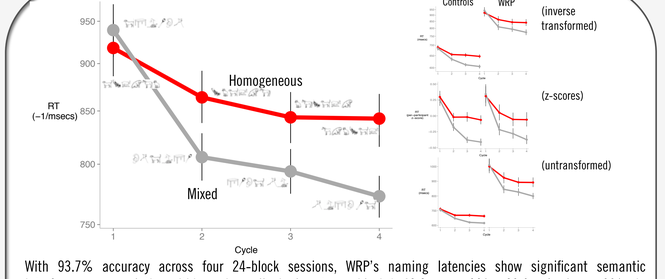
Cumulative semantic interference in blocked-cyclic picture naming does not require explicit memory, either

(e.g. Damian et al, 2001; Schnur et al, 2006)



When repeatedly naming a small set of exemplars from a single semantic category, people become slower relative to an unrelated baseline. This comparison figure from Schnur et al, 2006, shows blocked-cyclic naming latencies from 12 unimpaired controls (mean age=63), naming the line drawings on the left in American English. Error bars represent 95% CIs.

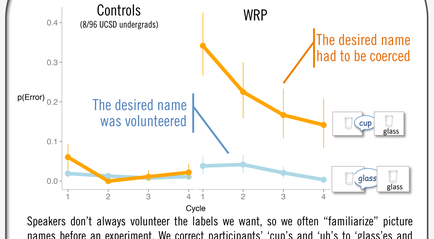
Our experiment, with WRP, used the same materials.



With 93.7% accuracy across four 24-block sessions, WRP's naming latencies show significant semantic interference accumulating within each small, single category block (~42.9ms, p<.001; ~23.0ms/cycle, p<.001; via maximal lmer of inverse-transformed correct RTs). After adjusting for nonsemantic RT differences, the magnitude of WRPs semantic interference effects closely approximate those of 8 'canonical controls' (UCSD undergrads from Oppenheim, in prep; on the left in the three panels on the right) who named the same lists, whether comparing via inverse-transformed (ps>.8), z-scores (ps>.7), or untransformed RTs (ps>.3).

To match the Schnur et al comparison figure, these error bars represent 95% CIs.

So what *is* the role of explicit memory in picture naming?



Speakers don't always volunteer the labels we want, so we often "familiarize" picture names before an experiment. We correct participants' 'cup's and 'uh's to 'glass'es and treat the resulting 'cup→glass'es in our experiments like normal 'glass'es (though we did exclude them here). Unimpaired speakers do adapt quite successfully, but their "coerced" names remain detectably slower and more error prone (Oppenheim, 2014; in prep). WRP's blocked cyclic naming accuracy reveals exaggerated difficulty adapting to such corrections (above right; inter-ocular), consistent with the intuition that they could turn "simple" picture naming into something more like an explicit memory task, testing the use of novel cue-response associations. (Again, error bars represent 95% CIs.)

Conclusions

- The temporal persistence of cumulative semantic interference has long-suggested a role for some kind of learning, but a challenge has been to distinguish implicit learning (e.g. Oppenheim et al, 2010) from explicit (e.g. de Zubicaray et al, 2014).
- Despite destruction of the left hippocampus and corresponding explicit memory impairments, WRP's picture-naming latencies show significant and apparently undiminished cumulative semantic interference in both major paradigms.
  - This pattern supports implicit learning accounts of both effects
  - Explicit memory is not central to either effect
  - To the extent that short-term and/or working memory are hippocampus-dependent (e.g. Jonides et al, 2008), these results also suggest limits on their contributions.
- Explicit memory may, however, play a role in adopting preferred names via pre-experiment familiarization procedures. This may be an example of 'arbitrary' stimulus-response binding even for ostensibly meaningful cues.

Acknowledgements

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