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Explicit and implicit reversal of musical and phonological stimuli

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Big Question: What causes inductive biases to be the same or different across different domains of experience?

Observation: Reversal patterns are rare compared to repetition patterns in **music** [3, 6], **phonology** [5], and **language games** [2, 1, 4] — even though nested dependencies are lower on the Chomsky Hierarchy than crossed ones [13]. Why does this happen?

Conjecture: Because auditory memory preserves time order, **repetition can be recognized *automatically* (implicitly)** when a chunk is matched and re-activated, but **reversal requires *deliberate* (explicit, effortful) reordering** in working memory [3, 9, 7]. Hence:

▶*H1*: As a *pattern* (i.e., characterizing a set of stimuli), reversal should be harder to discover than repetition, regardless of whether learning is implicit or explicit.

▶*H2*: As a *pattern*, reversal should only be discoverable with knowledge of the pattern (explicitly).

▶*H3*: In an *individual stimulus*, reversal should be harder to detect, even when the pattern is known in advance.

Experiments 1′ and 2′: Pseudowords [8]

Procedure: Participants were told they would learn to distinguish between "words" which fit vs. violated either an *undisclosed* pattern (Exp. 1, $N = 100$), or an *explicitly explained* pattern (Exp. 2, $N = 100$).

▶They were randomly assigned to Red(uplication) or Rev(ersal) groups.

▶On each of 50 trials, a different 7-syllable pseudoword was presented. They chose *yes* or *no*, received right/wrong feedback, went on to next trial.

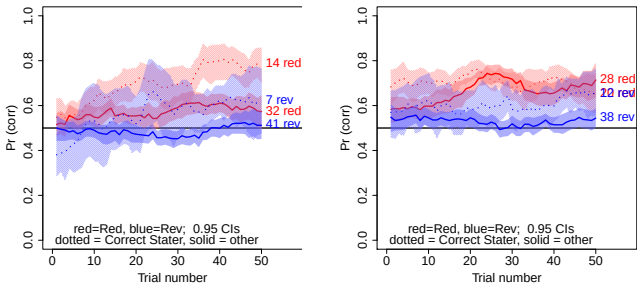
	Red(uplication):	Rev(ersal):
50%	*a b c d a b c* ko li ve su ko li ve	*a b c d c b a* ko li ve su ve li ko
	Non-conforming foils:	**Non-conforming foils:**
25%	*a b c d a c b* ko li ve su ko ve li	*a b c d c a b* ko li ve sy ve ko li
25%	*a b c d b a c* ko li ve su li ko ve	*a b c d b c a* ko li ve su li ve ko

Debriefing questionnaire: Responses were coded as "stated the correct rule" vs. "other" (i.e., wrong rule or no rule). Cohen's κ for inter-rater reliability was ≥ 0.61.

Analysis: Dependent measure was the participant's modelled accuracy at the end of the experiment ("final accuracy"). H1, H2, H3 were tested using planned comparisons.

Results: Learning curves show 13-trial moving average:

Exp. 1′ (uninformed) Exp. 2′ (informed)



(1′a) Red Corr Strs − Rev Corr Strs = 1.65 *logits*, $p < 0.0047$. *(1′b) Red Others − Rev Others* = 0.99, $p = 0.0052$. *(1′c) Rev Others* = −0.047, 95% *CI* = [−0.46, 0.37]. *Rev Corr Strs* = 1.61, 95%*CI* = [0.37, 2.85].

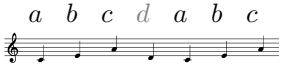
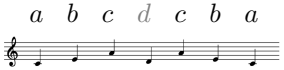
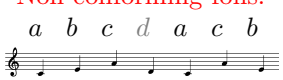
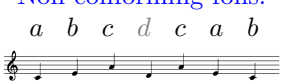
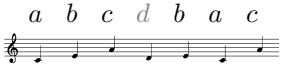
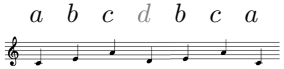
(2′a) Red Corr Strs − Rev Corr Strs = 0.56 *logits*, $p = 0.62$. *(2′b) Red Others − Rev Others* = 1.83, $p < 0.001$. *(2′c) Rev Others* = 0.23, *95% z CI* = [−0.18, 0.64]. *Rev Corr Strs* = 1.21, 95%*CI* = [0.96, 1.95].

H1: Red > Rev, for both groups? YES (1′a, 1′b). **H2**: Rev > 0 only for Correct Staters? YES (1′c, 2′c). **H3**: Red > Rev even when pattern known? MIXED (2′a, 2′b).

Further evidence that Reduplication is automatic and Reversal effortful: Among Correct Staters in the Reversal conditions of Expp. 1′ and 2′, participants with longer final response times had significantly greater final accuracy, but not in the Reduplication conditions, and not Others.

Experiments 1 and 2: Melodies

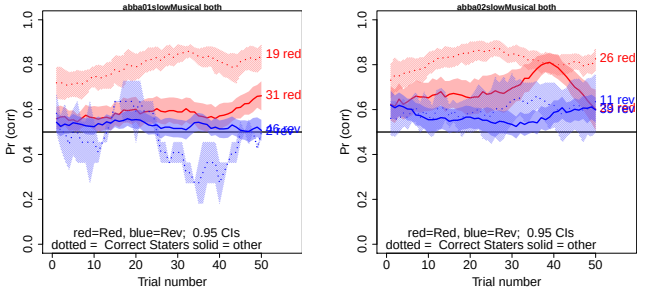
Procedure: Like Expp. 1′ and 2′, except with 7-note melodies instead of words, at 100 beats per minute.

	Red(uplication):	Rev(ersal):
	a b c d a b c	*a b c d c b a*
50%		
	Non-conforming foils:	**Non-conforming foils:**
	a b c d a c b	*a b c d c a b*
25%		
	a b c d b a c	*a b c d b c a*
25%		

Debriefing questionnaire: Cohen's κ for inter-rater reliability was ≥ 0.89.

Results: Learning curves show 13-trial moving average:

Exp. 1 (uninformed) Exp. 2 (informed)



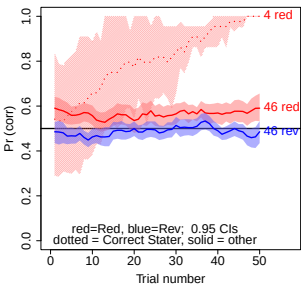
(1a) Red Corr Strs − Rev Corr Strs = 4.88 *logits*, $p < 0.001$. *(1b) Red Others − Rev Others* = 0.91, $p = 0.033$. *(1c) Rev Others* = 0.13, *95% CI* = [−0.31, 0.57]. *Rev Corr Strs* = −1.1, *95% CI* = [−3.3, 1.1].

(2a) Red Corr Strs − Rev Corr Strs = 2.22 *logits*, $p = 0.0074$. *(2b) Red Others − Rev Others* = 1.89, $p < 0.001$. *(2c) Rev Others* = 0.70, *95% CI* [0.10, 1.23]. *Rev Corr Strs* = 1.64, *95% CI* [0.47, 2.80]

H1: Red > Rev, for both groups? YES (1a, 1b). **H2**: Rev > 0 only for Correct Staters? MIXED (1c, 2c). **H3**: Red > Rev even when pattern known? YES (2a, 2b).

Experiment 3: Melodic contours

If rearranging notes makes Rev hard, would Rev improve if the melodies were treated holistically, as contours? (Rev in static visual contours is easy [12, 10, 11].)



Procedure: Like Exp. 1, but instructions spoke of "shape" (illustrated with animation) and urged participants to trace it in the air or in imagination.

Results: Correct Stating plummeted. Rev performance did not improve.

Reversal detection *requires* reordering in working memory.

Discussion

▶In nonwords and melodies, the effort of **rearrangement in working memory makes reversal hard**.

▶Do music and natural language ***always* favor automatic processes** over effortful ones? If not, when?

▶Shared cognitive resources lead to **analogous biases in two domains**. Where else does that happen?

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