Highlighting is amplified by two forms of prefrontal suppression

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Introduction

Highlighting is a trial order phenomenon in associative learning:

Learn	Test	Observed
AB>X	A>?	A>X
AC>Y	BC>?	BC>Y

EXIT (Kruschke, 2001) holds that attention accounts for the response asymmetry, with subjects attending to C but not A on AC trials. This leads to an asymmetry in association strengths:

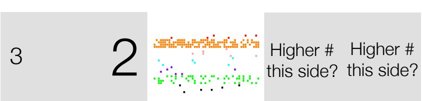
C>Y >> A>X = B>X >> A>Y

The strength of this asymmetry should be contingent on attentional competition, with sharper competition producing more highlighting. We thus set out with the following question:

Does reducing attentional resources amplify highlighting?

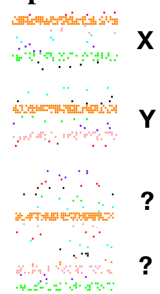
Methods: Experiment 1

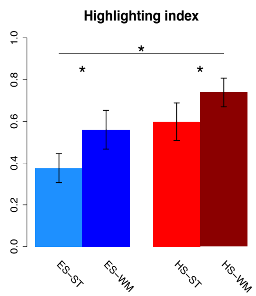
Procedure. Stimuli were colored grids, with each colored stripe constituting a cue (Denton & Kruschke, 2006). The experiment was structured with the three-phase design of Kruschke (2009). Subjects were randomly assigned to the equal-salience (ES) condition, in which the shared cue A had equal density to the unique cues, or the high-salience (HS) condition, in which the shared cue (A) had a higher density. All subjects completed the task with and without a secondary task taxing working memory (Filoteo et al., 2009):



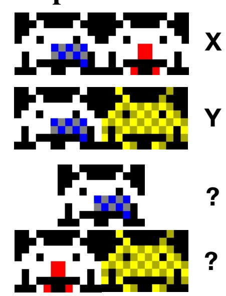
After training, subjects were tested on the learned associations as well as novel compounds A and BC, with no feedback given.

Experiment 1

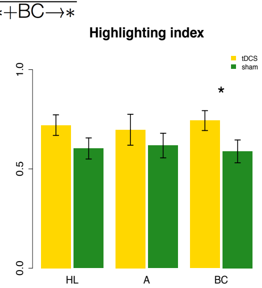




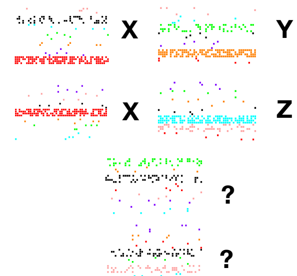
Experiment 2



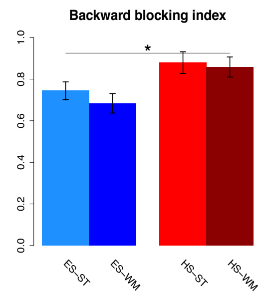
$$\frac{A\to X + BC\to Y}{A\to * + BC\to *}$$



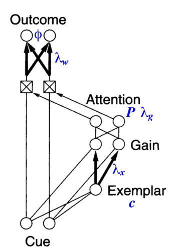
Experiment 3



$$\frac{B[CD]\to Y + B[EF]\to Z}{B[CD]\to * + B[EF]\to *}$$



EXIT Fits



parameter	HL-Behavioral ES-ST	HL-Behavioral ES-WM	HL-Behavioral HS-ST	HL-Behavioral HS-WM	HL-tDCS Stim	HL-tDCS Sham	BB-Behavioral ES-ST	BB-Behavioral ES-WM	BB-Behavioral HS-ST	BB-Behavioral HS-WM
c	0.001	0.003	7.49	0	0.003	0.001	0.23	0.001	0.2	0.001
P	1.2	1.24	2.47	2.12	1.065	0.659	0.55	0.75	0.62	1
ϕ	1.07	1.94	2.6	2.39	9.248	2.732	2.09	1.64	2.34	2.15
λ_g	2.03	2.29	8.78	3.01	0.731	1.567	0.77	2.24	0.74	2.26
λ_w	0.38	0.09	0.02	0.09	0.015	0.45	0.24	0.23	0.29	0.38
λ_x	0.01	0	2.76	0	0.016	0.008	0.005	0.013	0.005	0.008
σ	0.57	1.6	1.03	2.34	0.005	0.8	0.26	0.89	0.38	0.86
RMSE	0.23	0.14	0.14	0.13	0.0032	0.064	0.16	0.13	0.22	0.21

Methods: Experiment 2

Procedure. Stimuli were sprites from the game *Space Invaders* modified to show various "symptoms."

tDCS. The cathode was placed over left ventrolateral PFC (F7) and the anode over the right mastoid. Subjects either received 15 s of 1.5 mA tDCS ("sham") or were stimulated throughout the experiment, which took 10-15 minutes.

Methods: Experiment 3

Stimuli and procedure were identical to Experiment 1 except that we examined *backward blocking*:

Learn	Test	Observed
AB>X; CD>Y	B[CD]>?	B[CD]>Y
A>X; EF>Z	B[EF]>?	B[EF]>Z

Per EXIT, attentional capacity should affect HL and BB identically; Kalman filter model predicts opposite effects (Daw et al., 2008).

Discussion

- Highlighting and backward blocking pose problems for dominant theories of associative learning (Kruschke & Blair, 2000; Kruschke, 2009). Attention can account for them, but so can Bayesian models with reduced information about cue covariance (Daw et al., 2008).
- Reducing prefrontal activity via tDCS and occupying prefrontal resources via secondary task amplifies HL but does not reduce BB, *contra* Daw account.
- Attentional parameters of EXIT covary *paradoxically* with tDCS, salience, and WM effects in HL subjects, *increasing* attention capacity (*P*) and shift rate (λ_g).

- **Paradoxical fits problematize EXIT as a unifying account of HL and BB.**
- **HL effect without a BB effect problematizes the Kalman filter as a unifying account of HL and BB.**
- **Cognitive control appears relevant to HL but not BB, suggesting that the two phenomena are mediated by different learning systems.**

References

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