

BACKGROUND

- While much research has focused on the determinants of exploratory choice, less is known about the consequences of exploratory states for information processing.
- Exploration has been associated with changes in learning rate, the balance of bottom-up vs. top-down control, and norepinephrine-linked arousal [1, 2, 3].
- Additionally, exploration across tasks may rely on shared resources, as evidenced by priming between spatial and lexical search [4, 5].
- Here we ask whether exploratory choice in a bandit task will affect semantic fluency performance, which has been shown to resemble patch foraging [6].

Hypotheses

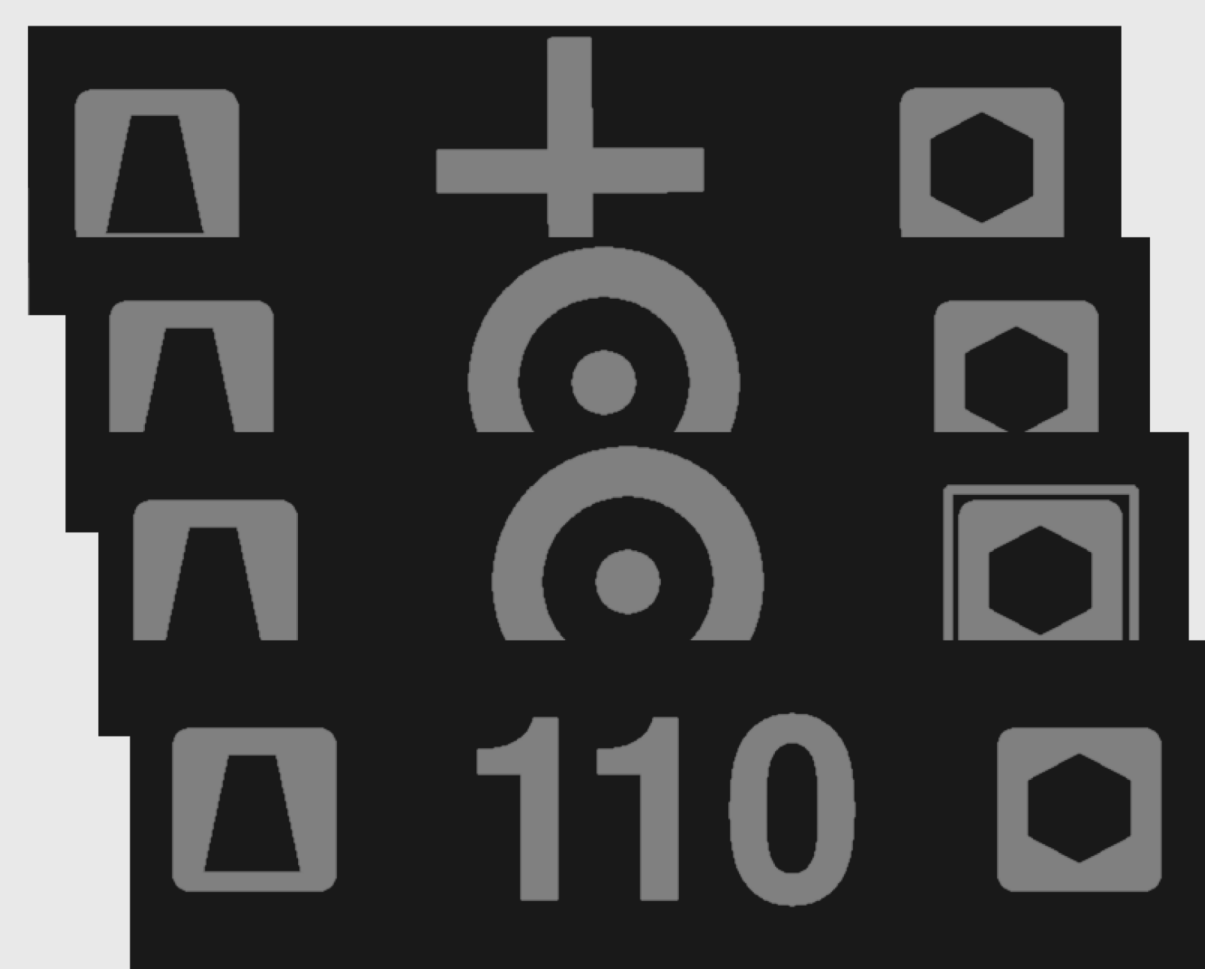
- H1: Global/Switching begets switching*—priming greater exploration in the bandit task will lead to more switching/decreased semantic similarity in semantic fluency
- H2: Local/Gain modulation*—arousal-induced increases in neural gain directly following exploration will increase semantic similarity/decrease switching by reducing semantic competition

METHODS

1. Leapfrog Bandit

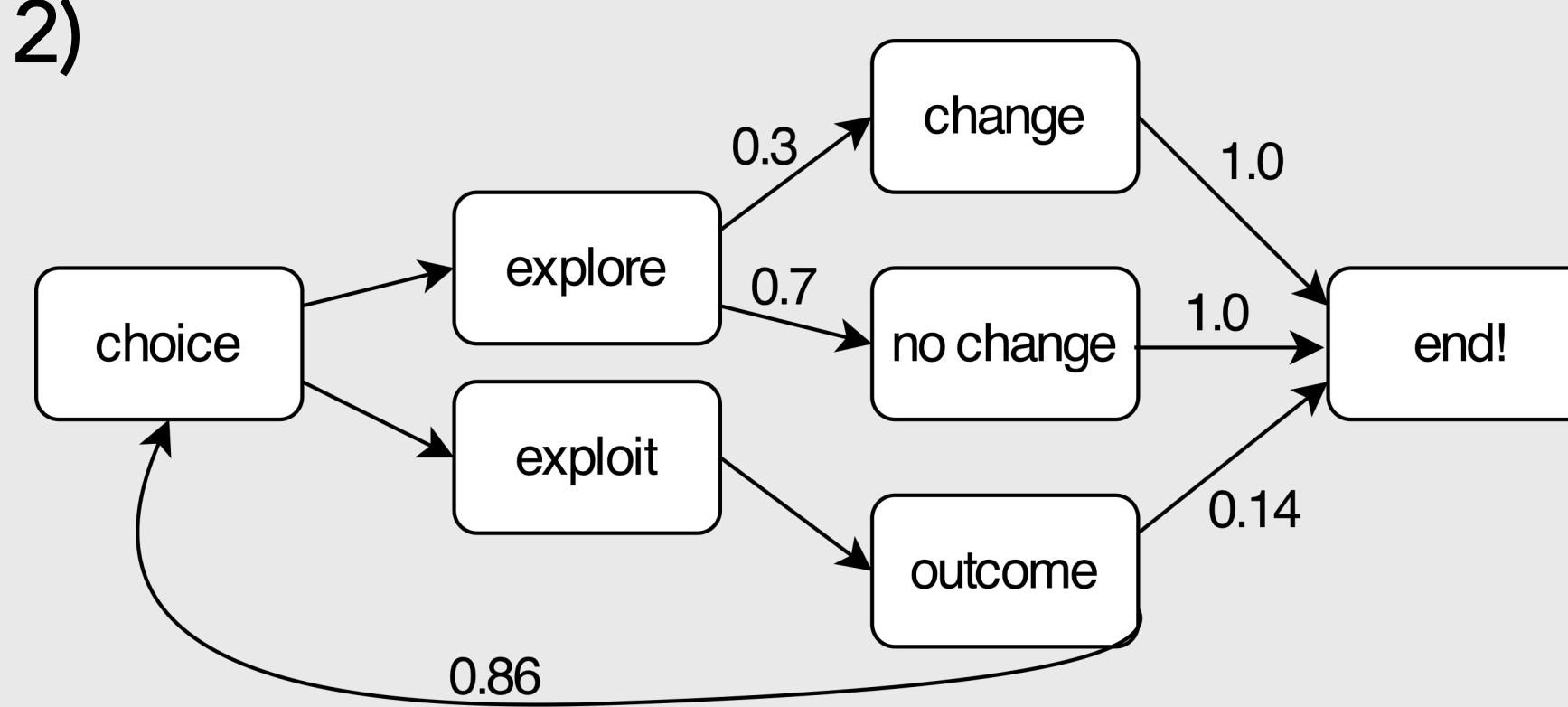
A simplified bandit task [7]

- 100 trials
- Two armed
- Deterministic reward
- Fixed distance between options
- Options “take turns” being the best, changing based on underlying P_{flip}
- Goal:** Always choose the option that is currently the best. Requires balancing *exploration* and *exploitation*.
- Two conditions: low volatility ($P_{flip} = 0.05$), high volatility ($P_{flip} = 0.20$)



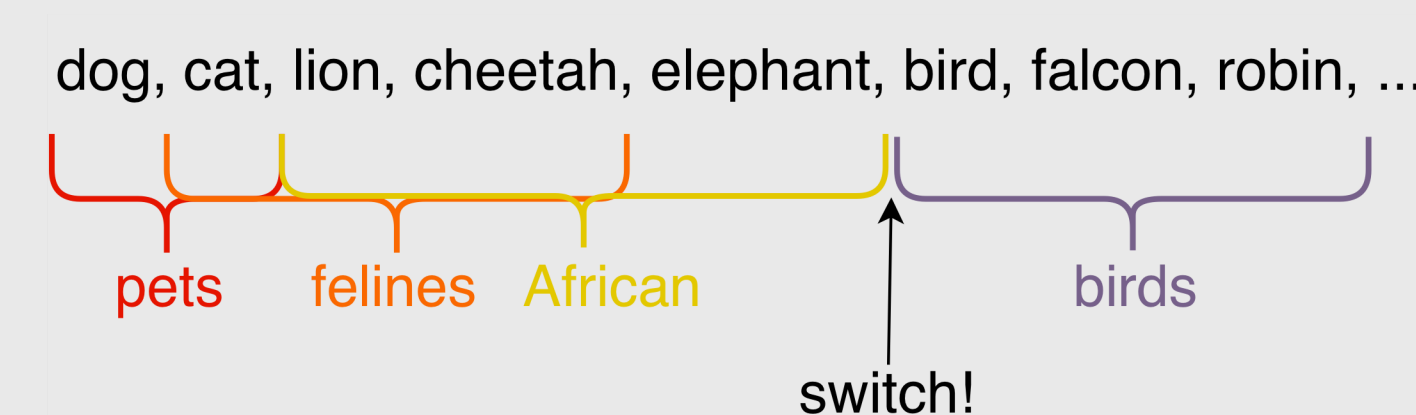
1a. Rigged Bandit (Study 2)

- Same as above except
- Low volatility only
- After trial 90, events dictated by altered probabilities
- Ensures a relatively even distribution of last explore/last change outcomes



2. Semantic Fluency

- Name animals for 75 s
- Scored for fluid clusters (proportion clustered words out of total fluency) and switches (transitions between words not belonging to the same cluster)
- Pairwise cosine similarity computed from vector space model [8]



Subjects

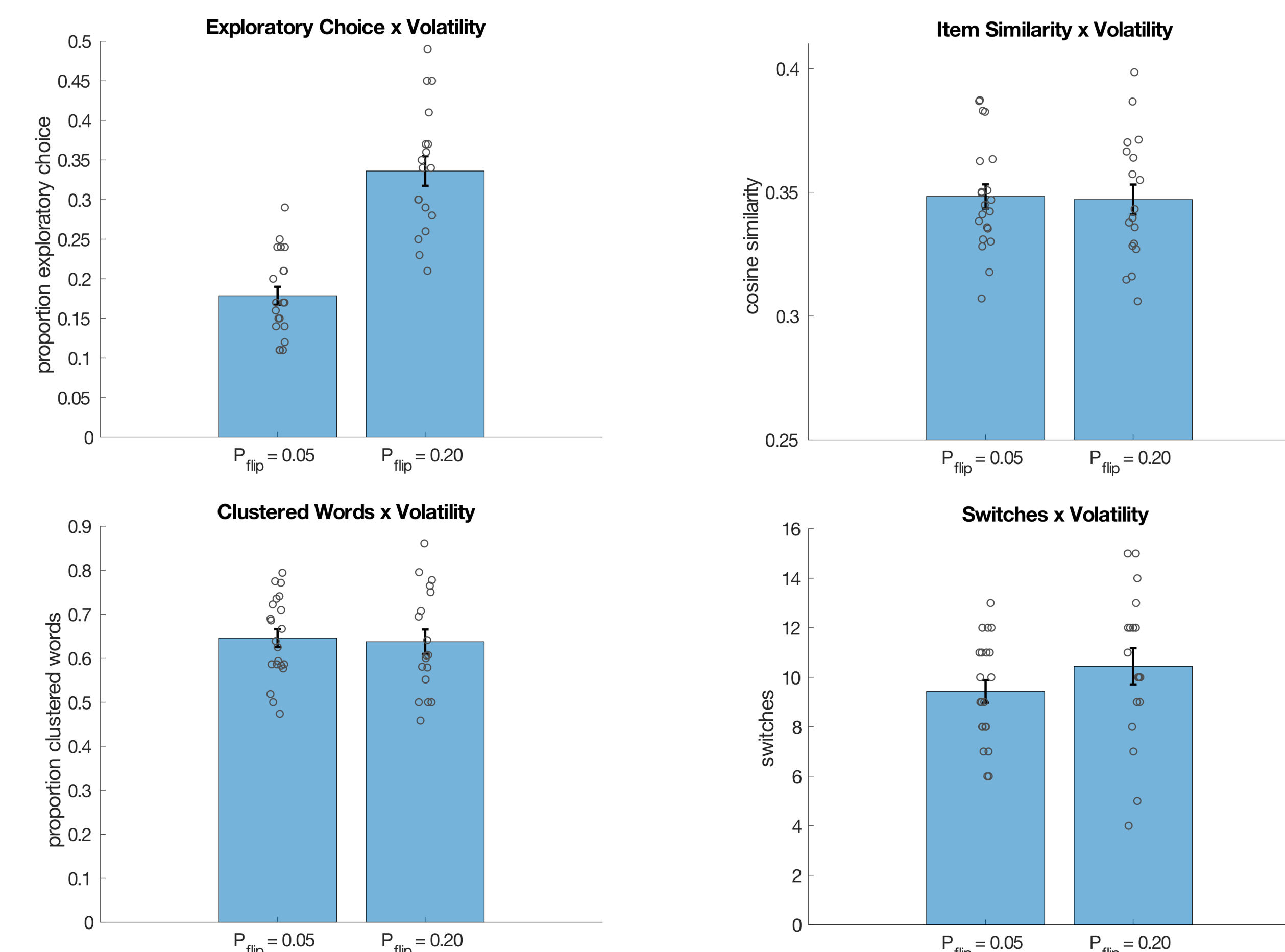
Study 1 (volatility manipulation): $N = 39$ [26 F, $M_{age} = 23.1$ (4.3); 21 low volatility, 18 high volatility]

Study 2 (last explore/change manipulation, low volatility): $N = 57$ [42 F, $M_{age} = 20.9$ (3.2); 18 explore/change, 22 explore/no change, 17 no explore/no change]

RESULTS

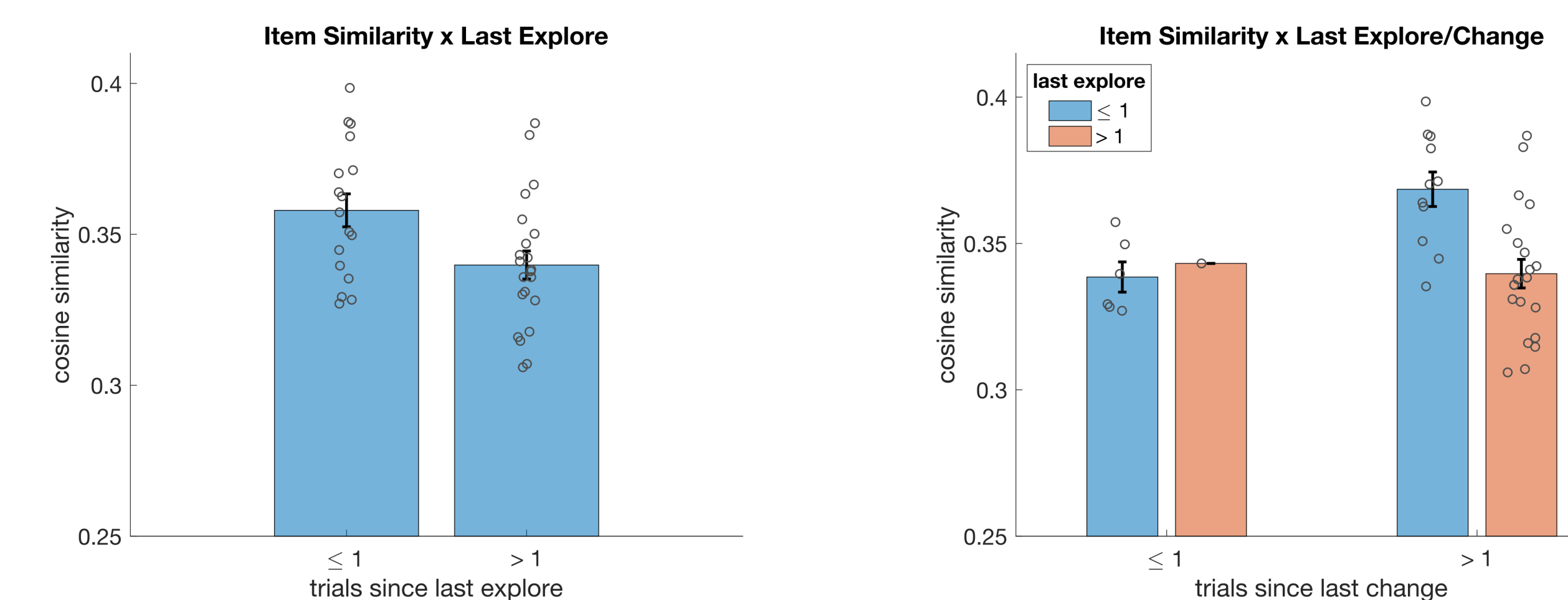
Study 1

Volatility Condition Effects



- Subjects explored to a greater degree in the high volatility than the low volatility condition ($M = 0.16$, $t(37) = 7.45$, $p < 0.0001$).
- But there were no differences between conditions in animal naming performance, including total fluency (not pictured; all $ps > 0.18$).

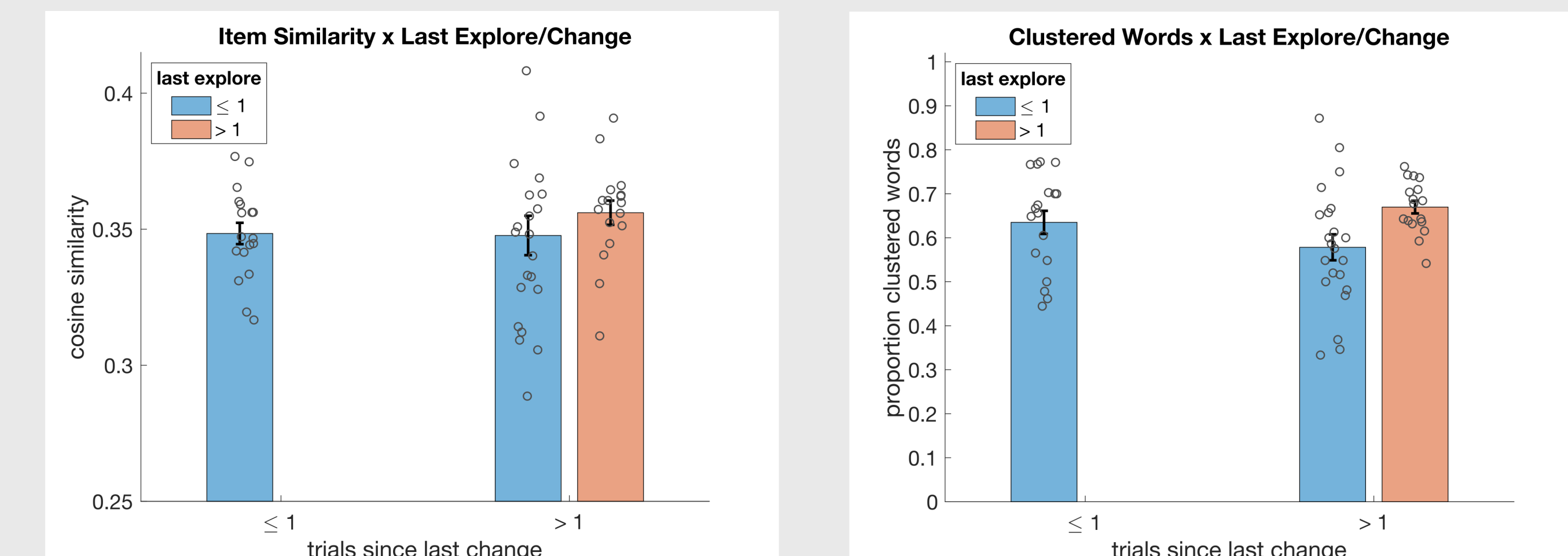
Local Effects



- Item similarity was greater when subjects explored on one of the last two trials prior to animal naming (*left*; $M = 0.018$, $t(37) = 2.53$, $p = 0.016$). No other differences were significant (all $ps > 0.17$).
- This effect was driven by those who explored and did not see a change (*right*), who had significantly greater item similarity than explore/change ($M = 0.030$, $t(15) = 3.37$, $p_{corrected} = 0.008$) and no explore/no change ($M = 0.029$, $t(30) = 3.61$, $p_{corrected} = 0.003$). There was no difference between explore/change and no explore/no change ($M = -0.001$, $t(25) = -0.12$, $p_{corrected} = 0.91$).

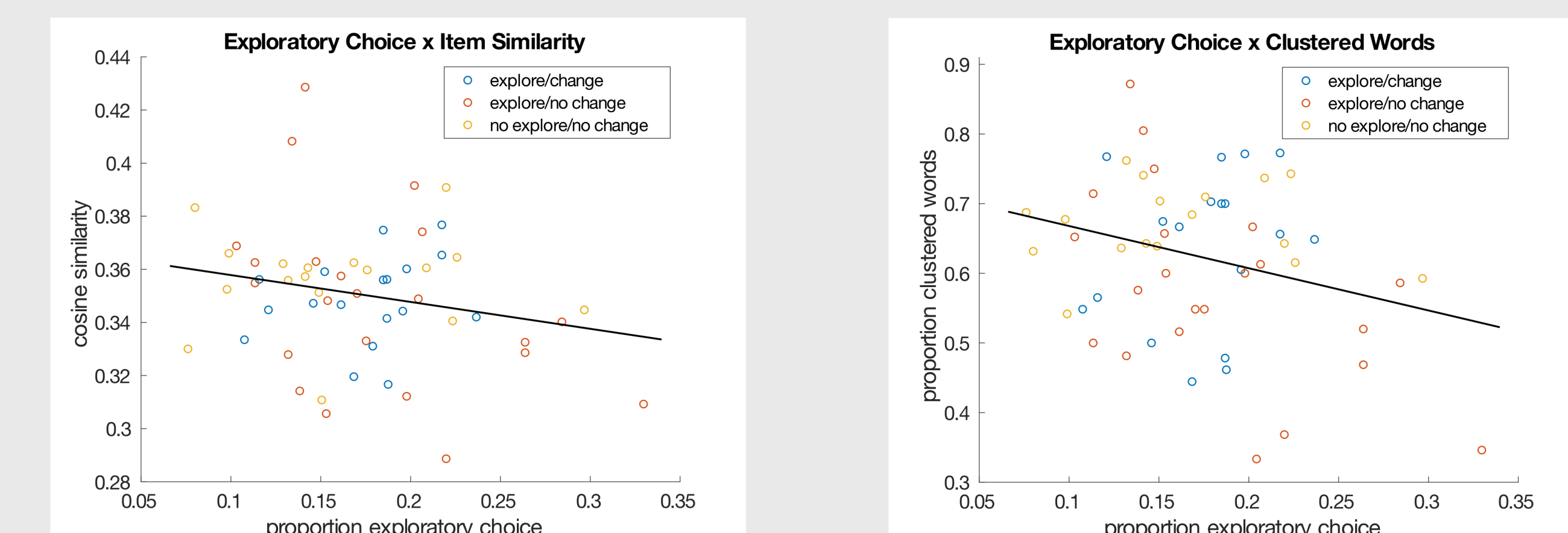
Study 2

Local Effects

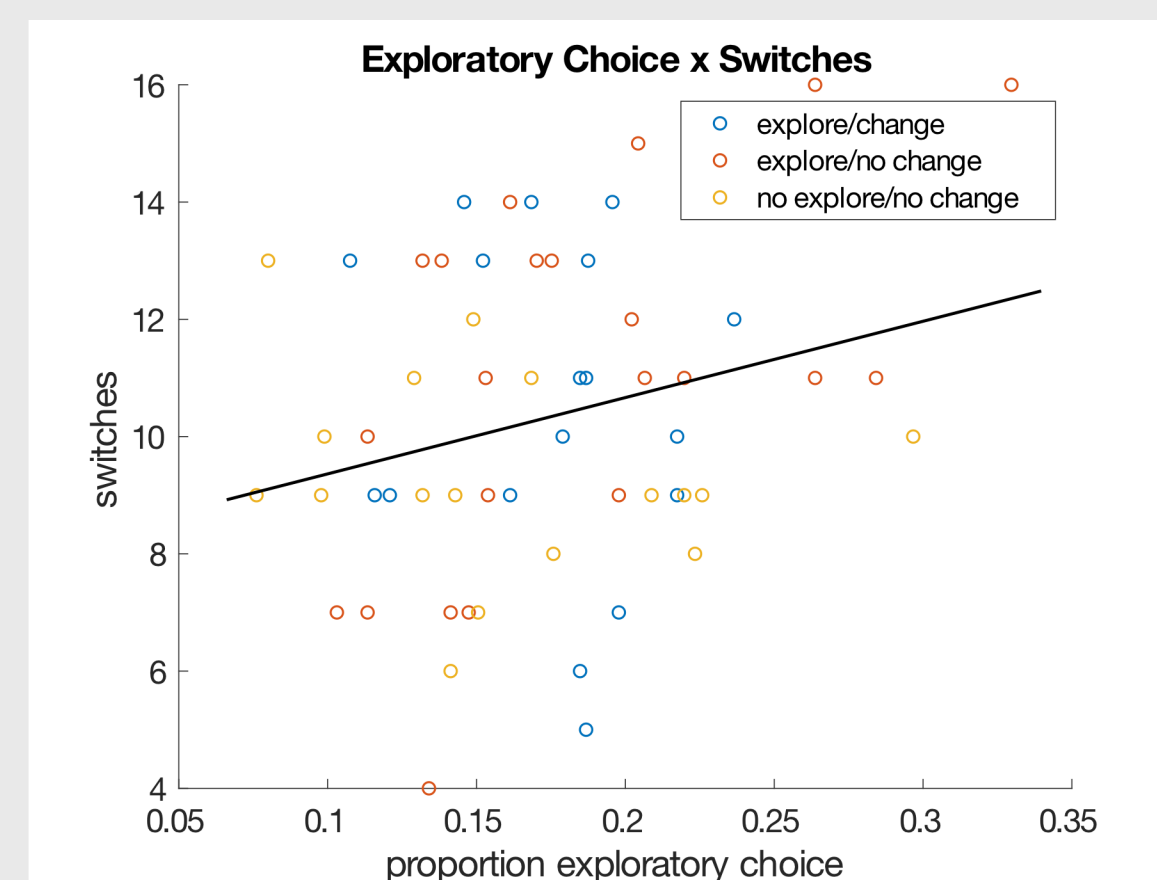


- The item similarity effect failed to replicate (*left*; all $ps_{corrected} > 0.61$).
- However, the explore/no change group had a significantly reduced proportion of clustered words compared to no explore/no change (*right*; $M = -0.092$, $t(37) = -2.55$, $p_{corrected} = 0.046$). There were no other significant differences on this or other measures (all $ps_{corrected} > 0.23$).

Individual Differences in Exploration



- Exploratory choice was significantly correlated with clustered words ($r(55) = -0.28$, $p = 0.036$) and correlated at a trend level with item similarity ($r(55) = -0.22$, $p = 0.11$) and switches ($r(55) = 0.25$, $p = 0.056$).
- Correlations were driven by the explore/no change group (item similarity: $B = -0.25$, $t(50) = -2.63$, $p_{corrected} = 0.03$; clustered words: $B = -1.16$, $t(50) = -2.91$, $p_{corrected} = 0.016$; switches: $B = 29.61$, $t(50) = 3.06$, $p_{corrected} = 0.01$; $ps_{corrected}$ from other groups all > 0.59).



SUMMARY & CONCLUSIONS

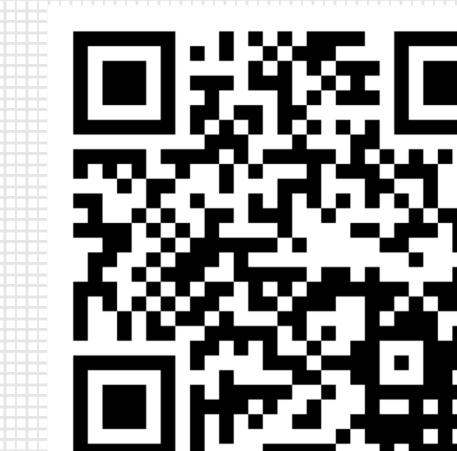
- There was no effect of bandit environmental volatility on animal naming (H1).
- Effects of recent choice and outcome were inconsistent between studies (H2), potentially reflecting noise or an interaction with volatility condition.
- However, the explore/no change group exhibited differential performance in both studies, suggesting that frustrated expectations in the bandit task carried over into animal naming, altering foraging in semantic space. This effect interacted with individual differences in overall bandit exploration.

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REFERENCES

- Ebitz, Albarran, & Moore (2018). *Neuron*.
- Ebitz & Moore (2016). *Gordon Research Seminar*.
- Aston-Jones & Cohen (2005). *Annu. Rev. Neurosci.*
- Hills, Todd, & Goldstone (2010). *J. Exp. Psychol. Gen.*
- Hills, Jones, & Todd. (2012). *Psychol. Rev.*
- Knox et al. (2012). *Front. Psychol.*
- Hills, Todd, & Goldstone (2008). *Psychol. Sci.*
- Mandera, Keuleers, & Brysbaert (2017). *J. Mem. Lang.*