The mechanisms of selection-for-action on visual working memory representations

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Introduction

We shape our perception of visual stimuli according to their relevance to a pre-determined task. Objects in our environment are inherently neutral, and thus we must weigh them based on their importance to our goals. Therefore, we quickly filter stimulus information contingent with these weights, leading to a "selection-for-action" [1] within visual working memory (VWM).

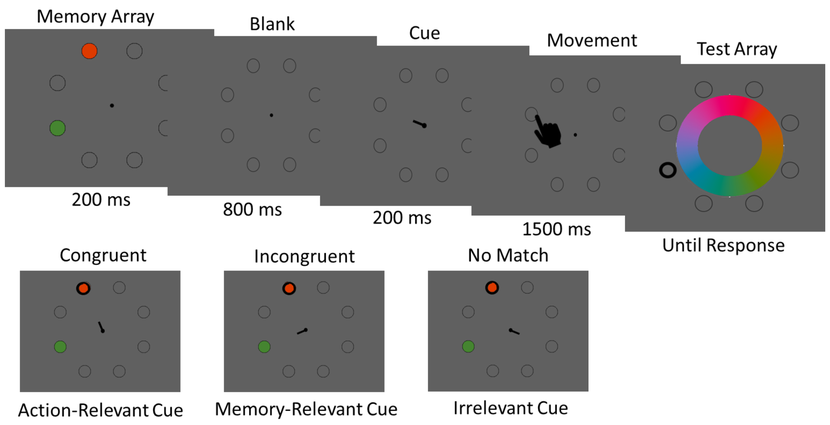
Recent work has shown that VWM representations can be modulated if they are associated with the location of a motor movement.[2] Specifically, making a manual movement to the to-be-tested item's location improved change detection performance compared to when the movement was made to one of the non-targets.

Research Question:

Does motor action modulate action-relevant items, action-irrelevant items or both?

In the present study, our aim was to determine how manual movements modulate visual working memory representations. Specifically, we asked whether a pointing movement to a location enhances memory representation that was presented at that location, inhibits representations at other locations, or a combination of these processes.

Method



We modified the task used in Heuer et al. (2017), where participants were presented with color stimuli for a later memory test. We then presented a movement cue pointing to one of the locations. In separate blocks, participants were either asked to touch the cued location on the screen or ignore the cue. At the end of each trial, they were asked to report the color of one of the memory items on a continuous space.

Conditions

Motor Movement: No Movement, Movement
Congruency: No Match (irrelevant), Incongruent (memory-relevant), Congruent (action-relevant)
Set Size: Set Size 2 (Experiment 1), Set Size 4 (Experiment 2)

Analyses

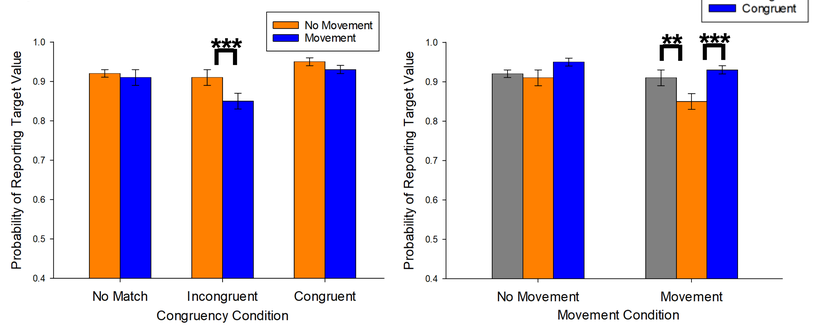
Subjects' response distributions were fitted with a probabilistic mixture model using MATLAB Memtoolbox[4] to calculate the probabilities of reporting the target color value (Pt), a distractor (Pd), and a randomly chosen color value (Pr), as well as the precision (i.e., standard deviation) of the target reports. We also tested the effects of motor action and congruency on absolute errors in color reports.

If the motor action to the target location **enhances** action-relevant memory representations, then we expect to find significantly larger Pt values and more precise reports (i.e., smaller standard deviations) for Move-Congruent than for No Move-Congruent. We also expect Move-Congruent trials to have better memory compared to Move-No Match and Move-Incongruent.

If the motor action to the non-movement locations **inhibits** those memory representations, then we expect to find significantly smaller Pt values and larger standard deviations for Move-Incongruent than for No Move-Incongruent. We also expect to find worse memory for Move-No Match and No Move-No Match.

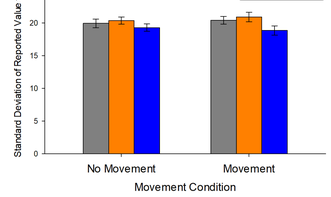
Experiment 1 Results

*p<.05
**p<.01
***p<.001



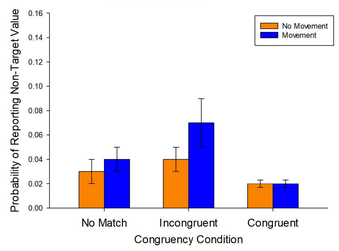
Target reports (pt):

- Effect of motor movement (*p*<.001): Making a movement led to lower target reports than not making a motor movement.
- Effect of congruency (*p*<.001): Congruent led to higher target reports than No Match (**enhancement**) which was significantly better than Incongruent (**inhibition**).
- Interaction (*p*=.015)*:* Making a movement led to lower target reports only for Incongruent condition (*p*<.001), indicating a significant **inhibition** of non-target locations with motor movement.
- Comparison of the Move trials: Moving to the Incongruent location led to worse target reports than Congruent (*p*<.001) and No Match (*p*=.002) trials (**inhibition**). No evidence for enhancement in the Congruent location compared to No Match location (*p*=.071).



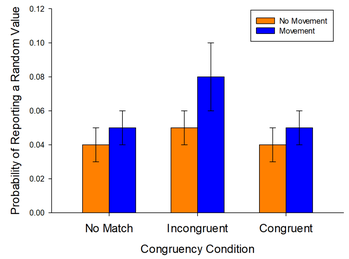
Standard Deviations (precision):

- Congruent condition led to more precise color reports (**enhancement**) than No Match and Incongruent, but no difference between No Match and Incongruent.
- No effect of Movement, No interaction



Non-target reports (pn):

- Movement led to higher non-target reports than No Move (*p*=.018).
- Congruent had the fewest non-target reports, followed by No Match and then Incongruent
- No interaction

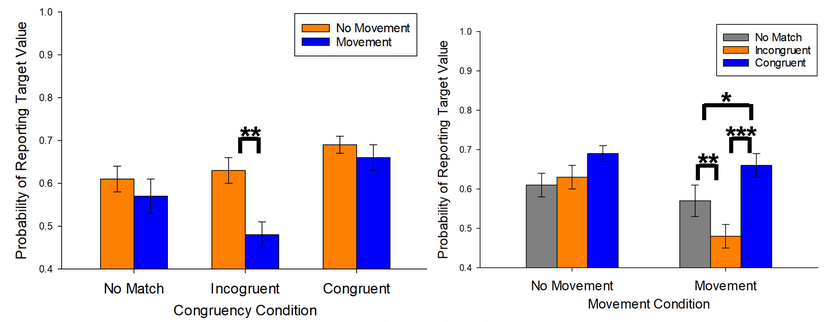


Random Guessing (pr):

- Movement led to higher guessing than No Move (*p*=.021).
- No effect of Congruency, No interaction

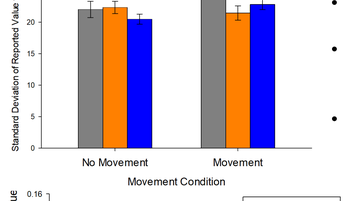
Experiment 2 Results

*p<.05
**p<.01
***p<.001



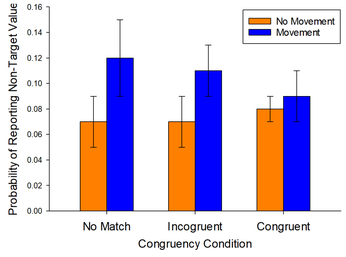
Target reports (pt):

- Effect of motor movement (*p*<.001): Making a movement led to lower target reports than not making a motor movement.
- Effect of congruency (*p*<.001): Congruent led to higher target reports than No Match (**enhancement**) and Incongruent, but no difference between No Match and Incongruent.
- Interaction *(p*<.001)*:* Making a movement led to lower target reports only for Incongruent condition (*p*<.001), indicating a significant **inhibition** of non-target locations with motor movement.
- Comparison of the Move trials: Moving to the Incongruent location led to worse target reports than Congruent (*p*<.001) and No Match (*p*=.003) (**inhibition**). Congruent led to better target reports than No Match (*p*=.016) (**enhancement**).



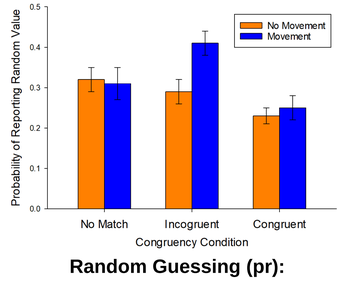
Standard Deviations (precision):

- Movement led to less precise color reports than No Move (*p* = .028).
- Congruent condition led to more precise color reports (**enhancement**) than No Match. No other significant differences.
- Movement decreased report precision in Congruent (*p* = .013), but not in other conditions.



Non-target reports (pn):

- Movement led to higher non-target reports than No Move (*p*=.017).
- No effect of Congruency, No interaction



Random Guessing (pr):

- No effect of Movement
- Congruent had fewer guessing than both No Match and Incongruent
- Movement significantly increased random guessing in the Incongruent condition (*p*<.001) (**inhibition**).

Conclusions

1. We found significant evidence for **inhibition of action-irrelevant items**:
   - Manual movements to the Incongruent location significantly decreased target reports compared to No Move control.
   - For these Incongruent Move trials, participants instead reported a random color value, rather than non-target values, suggesting that all non-movement color values were inhibited.
   - When participants made a manual movement, Incongruent condition consistently resulted in worse performance than No Match control.
2. Replicating Heuer et al. (2017), Congruent Move trials at SS4 showed **enhancement of action-relevant items** compared to No Match and Incongruent.
3. Inhibition is a more likely explanation for the motor effects on VWM representations than enhancement.

References

[1]Allport, D. A. (1987). Selection for action: Some behavioural and neurophysiological considerations of attention and action. In H. Heuer & A. F. Sanders (Eds.), Perspectives on perception and action (pp. 395–419). Hillsdale: Erlbaum.
[2]Heuer, A., Crawford, J. D., & Schubö, A. (2017). Action relevance induces an attentional weighting of representations in visual working memory. Memory & Cognition, 45(3), 413–427. https://doi.org/10.3758/s13421-016-0670-3.
[3]Heuer, A., Ohl, S., & Rolfs, M. (2020). Memory for action: A functional view of selection in visual working memory. Visual Cognition, 28(5–8), 388–400. https://doi.org/10.1080/13506285.2020.1764156.
[4]Suchow, J.W., Brady, T. F., Fougnie, D., & Alvarez, G. A. (2013). Modeling visual working memory with the MemToolbox. Journal of Vision, 13(10):9, 1–8, http://www.journalofvision.org/content/13/10/9, doi:10.1167/13.10.9.