Working Memory for Spatial Location is Attracted Towards the Focus of Attention

Jeffrey S. Johnson (jeffrey-johnson-2@uiowa.edu)
Department of Psychology, E11 Seashore Hall
Iowa City, Iowa 52242 USA

John. P. Spencer (john-spencer@uiowa.edu)
Department of Psychology, E11 Seashore Hall
Iowa City, Iowa 52242 USA

Keywords: spatial attention; spatial working memory; neural modeling; dynamic systems theory

Attention and working memory are closely related cognitive processes that play an important role in many everyday behaviors. Although most research has focused on examining these two processes in isolation, exploring and understanding the relationship between attention and working memory has become a central focus of research in this area. In the present study, we examine this issue with a combination of behavioral experimentation and neural modeling, focusing on interactions between spatial attention and spatial working memory (SWM).

Behavioral and brain imaging studies have suggested a close relationship between systems of spatial attention and of SWM. For example, in an elegant series of behavioral experiments, Awh and colleagues (Awh, Jonides, & Reuter-Lorenz, 1998) demonstrated that discrimination performance was both faster and more accurate for stimuli appearing at locations that were being maintained in SWM, a benefit that is commonly found for attended locations (Posner, 1980). In a second experiment, they showed that performance of a same/different location memory task was impaired when attention was shifted away from the memorized location to perform a secondary load task during the delay interval, suggesting that attention plays a functional role in the maintenance of information in SWM. Similarly, brain imaging studies (Awh et al., 1999; Postle, Awh, Jonides, Smith, & D'Esposito, 1999) have revealed that maintaining information in SWM leads to increased activation in many of the same brain areas that are activated in experiments probing spatial attention.

On the basis of these findings, Awh et al. (1998) proposed that rehearsal (i.e., maintenance) in SWM is mediated by covert shifts of spatial attention to memorized locations. However, this is not the only possibility suggested by the findings discussed above. Another possibility is that attending to a location other than the one you are holding in memory systematically distorts this memory, making it more difficult to detect location changes at test.

To test this proposal, we had participants perform a spatial recall task with the addition of a color-discrimination task requiring shifts of spatial attention during the delay. Previous studies of spatial recall have revealed that metric memory for location is biased away from salient axes of reference (e.g., the midline symmetry axis of the task space) across delays (Spencer & Hund, 2002). In our experiment, color targets could appear either in the direction of these biases (i.e., away from midline relative to the memory target), or in the opposite direction (i.e., toward midline). Our results revealed that shifting attention had a systematic effect on the patterns of spatial error produced in this task. Specifically, when attention was shifted in the direction of drift, spatial errors increased in the same direction, whereas when attention was shifted in the opposite direction, errors were reduced but not eliminated. Such modulations of spatial error could have contributed to the increase in errors found in the studies of Awh et al.

We simulate these findings using the dynamic field theory (DFT), a multi-layer neural-network model of SWM. These findings can be accounted for with the DFT if we assume that performance of the color-discrimination task provides an extra source of subthreshold location-specific excitatory input into the SWM layer of the model during the delay. This modeling work highlights the importance of moving to a more formal approach to working memory and attention in that the concept of "rehearsal" could have many meanings within our theoretical framework.

References

Awh, E., Jonides, J., & Reuter-Lorenz, P. A. (1998). Rehearsal in spatial working memory. *Journal of Experimental Psychology: Human Perception and Performance, 24*, 780-790.

Awh, E., Jonides, J., Smith, E. E., Buxton, R. B., Frank, L. R., Love, T., et al. (1999). Rehearsal in spatial working memory: Evidence from neuroimaging. *Psychological Science, 10*, 433-437.

Posner, M. I. (1980). Orienting of attention. *Quarterly Journal of Experimental Psychology, 32*, 3-25.

Postle, B. R., Awh, E., Jonides, J., Smith, E. E., & D'Esposito, M. (1999). The where and how of attention-based rehearsal in spatial working memory. *Cognitive Brain Research, 20*, 194-205.

Spencer, J. P., & Hund, A. M. (2002). Prototypes and particulars: Geometric and experience-dependent spatial categories. *Journal of Experimental Psychology: General, 131*, 16-37.