Study Debriefing

Thank you for participating in our study!

It has been proposed that the brains evolved to allow an organism to move. But today movement is often regarded as one of the brain's more rudimentary responsibilities, and more focus is put on the human brain's cognitive abilities, such as language processing, social navigation, and synthesizing ideas, all of which rely on "working memory". Working memory is short-term memory used to serve an ongoing task and is often studied in relation to visual and linguistic capabilities. For example, to keep a conversation going you require working memory to remember what has just been said. However, working memory is also of fundamental importance when it comes to learning how to move. Imagine learning any motor skill, from walking to tennis, we rely on working memory to let us know what works, what doesn't, and how to change it. And yet little is known about motor working memory.

Hypotheses and main questions:

As neuroscience progresses, we can detect increasing connections and co-activations between the parts of the brain thought to be solely responsible for cognition or for motor function. If we are to believe the theory that brains evolved for movement this is not so surprising, as all cognitive abilities would have developed from an infrastructure originally intended for motor function. [1]

We hypothesize that motor working memory may be based on at least two components: (1) a sensational component, that is, how it feels to move, and (2) an abstract spatial mapping component, that is, where in space we move relative to our body and our environment. [2] We want to test this theory by teasing apart these two components in our study and assessing their relative contributions to motor working memory.

Furthermore, we are interested in how motor working memory compares to other expressions of working memory (e.g., visual and linguistic). If we find that motor working memory is subject to the same constraints and vulnerabilities as other types of working memory, we may be able to look for a common underlying process that may be tested in future experiments.

How was this tested?

Each trial of the experiment is comprised of three phases: (1) learning, (2) maintenance, (3) recall. During the learning phase the robotic arm moves participants to one or more target locations. By varying the number of locations, we can test how many items motor working memory can hold under these conditions. During the maintenance phase, participants must maintain the information encoded in the learning phase. And finally, in the recall phase, participants are asked to recall one or more target locations, and if applicable, the order of these locations. For example, they may receive a prompt like, "Please recall movement #2" To answer, participants guide the robotic arm to the recalled location, pause, and then return the arm to the home location.

In addition to varying the amount of target locations, there are several experimental conditions which may be tested during the maintenance phase. In the "control" condition, participants merely wait a designated amount of time prior to the recall prompt. The "temporal decay" condition is just like the control condition, except that the waiting time is varied from trial to trial, thus allowing us to test how long information can be maintained and how it degrades. In the "wipeout" condition, the robotic arm moves participant's arm/hand to different target locations which provides a kind of passive interference. Passive interference is a well-studied concept in other forms of working memory and basically it acts as noise, making it more difficult to focus on the information one wants to maintain. Finally, there is the "hand-switch" condition, which asks participants to switch hands during the maintenance phase. Because the hand/arm that did the learning is no longer the one doing the recollection, the brain can no longer rely on the sensation-based "how it feels" component of motor working memory. In this condition we can investigate our primary question by regarding the error (distance between the location learned and location recalled) difference between the control and hand-switch conditions as the amount of information contributed to working memory based on the sensation component.

Why is this important to study?
The insights of this study can help us better understand motor working memory in healthy individuals. It can also provide important clues to what may happening in individuals who suffer from an inability to perform motor and memory functions.

What if I want to know more?
If you are interested in learning more about this study or cognitive motor adaptation, you may want to consult:

[1] Marvel, C. L., Morgan, O. P., & Kronemer, S. I. (2019). How the motor system integrates with working memory. In Neuroscience and Biobehavioral Reviews (Vol. 102, pp. 184–194). https://doi.org/10.1016/j.neubiorev.2019.04.017

[2] Bernardi, N. F., Darainy, M., & Ostry, D. J. (2015). Somatosensory contribution to the initial stages of human motor learning. Journal of Neuroscience, 35(42), 14316–14326. https://doi.org/10.1523/JNEUROSCI.1344-15.2015

If you are interested in learning more about this study, please contact Hanna Hillman, (612) 965-7026, hanna.hillman@yale.edu.

If you have concerns about your rights as a participant in this experiment, please contact the Human Subjects Committee, (203) 785-4688, human.subjects@yale.edu.

Please do not disclose research procedures and hypotheses to anyone who might participate in this study as this could affect the results of the study. Thank you for your participation!