Extending the Embodied Simulation Hypothesis: Effects of Motor Simulation in the Mind on Memory Retrieval

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Abstract: The *embodied simulation hypothesis* of modality-specific areas activation influencing language processing has matured over time. However, whether the idea can be applied to broader aspects other than language processing, such as memory processing, remains to be investigated. In this study, we extend the embodied simulation hypothesis, looking at the effects of motor simulation in mind, specifically handedness, on long-term memory retrieval. To test our hypothesis, we introduce two lists of Chinese characters as materials for memory and use old/new recognition tasks to measure retrieval performance. Our prediction of the results is that interfering with relevant motor systems (dominant hand) involved in memory encoding during retrieval will impair a person's ability to recall. If our experimental results support our hypothesis, this not only provides strong evidence for the embodied simulation hypothesis but our research may also be applied to the field of memory, providing potential inspiration for memory enhancement.

1. INTRODCUTION

According to the *embodied simulation hypothesis* (Casasanto, 2022)[1], modality-specific areas influence language processing. The proposed study will expand this hypothesis from language processing to memory processing using handedness as the representation of the motor system.

1.1. Specific aims

To test whether interfering with the relevant motor system (in this case dominant hand) causes impairment in memory retrieval.

1.2. Background

The way our bodies influence how we think and speak is well explained by the term “embodiment" in cognitive science (Varela et al., 1991)[2]. However, back in the 1950s, the idea of “mind is a computer” was prevalent in the field, which was the exact opposite of what we currently know about the mind by suggesting that the mind is computational and disembodied, that the way we think does not depend on our bodily experience. The revolution of embodied cognition started from the critiques of Descartes ’mind-body dualism by philosophers like Merleau Ponty, who argues that the body structures one’s situation and experience within the world (2013)[3]. More evidence arises supporting the idea that the mind, at least in part, depends on the motor and sensory experiences acquired by our bodies. For example, the study conducted by Wexler et al. illustrates that a change in the speed of motor rotation correspondingly changes the rate of a mental process (1998)[4].

Theories of embodied cognition have matured over time. Bergen put the concept of embodied simulation in his book Louder than words: The new science of how the mind makes meaning (2012)[5]. Embodied simulation refers to how we understand language's meaning by mentally simulating an experience described by language, which comes from our memory of experiencing the event. Surprisingly, the fundamental idea of embodied simulation was first proposed by Wernicke a century ago,

For example, the word "bell" concept is formed by the associated memory images of visual, tactual, and auditory perceptions. These memory images represent the essential characteristic features of the object, the bell.

(Wernicke 1977 [1874]: 117)[6]

Wernicke’s idea is the principle of the Embodied Simulation hypothesis, suggesting that understanding the meaning of words requires activation of modality-specific experiences, including perceptual, motor, and affective processes (Bergen, 2015)[7]. Furthermore, much research based on the Embodied Simulation hypothesis has done successful tests in support of the idea. Hauk et al.’s fMRI studies show that when passively reading the action words, people activated the same motor and premotor cortex as when they did actual movements (2004)[8].

According to the embodied simulation hypothesis, modality-specific areas play a causal role in processing word meaning (Casasanto, 2022)[1]. This proposal expands

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the scope of this hypothesis from processing word meaning to memory; more specifically, we introduce handedness as the independent variable. Our proposal suggests that if you learn a new foreign character via writing with your dominant hand, your memory for that character will depend at least partly on your motion experience of writing that character. Thus, a motor simulation in your mind will happen during the retrieval of memory based on the embodied simulation hypothesis, which means interfering with the relevant motor system should impair people’s ability to recall the characters.

1.3. Proposed study

The proposed study addresses whether the embodied simulation hypothesis from language processing to memory processing uses handedness as the representation of the motor system. In other words, disruption in the dominant hands, which people use to reinforce memory encoding, would decrease the retrieval process.

To address this question, we will conduct a study involving an old/new recognition task, which is a simple test in which the participants need first to memorize a list of items (such as a graph or words) to decide then if a thing from a new list is old or new. This task relies on recognition memory, and contrasts recall memory tests where participants must reproduce previously memorized items (Mulligan et al, 2010)[9]. In the proposed study, we will assign the participants to finish the task; then, we will evaluate the outcome and assess the data to see if our addressed question is answered.

2. HYPOTHESIS

H1. Memorizing a character via writing causes memory for that character to depend, in part, on the (dominant hand) motor system.

H0. Memory for visually presented characters will be purely visual and won't depend on the motor system.

3. METHOD

3.1. Participants.

We will recruit 160 undergraduate students to participate in our study. Half of them will be right-handed, and the other half will be left-handed. To be eligible for our study, the participants must be: (1) unknown of any Chinese or Japanese (since Japanese have some characters that are the same as some Chinese characters); (2) free from any diagnosed manual or anamnestic disability; (3) voluntarily to participate.

3.2. Material.

The material in this study will be two lists of simple Chinese characters, such as "心” “五” “于” “手” “天". List 1 will contain 60 Chinese characters; List 2 will have 120 Chinese characters, which include all 60 characters in List 1, and new characters in List 2 will be evenly and randomly distributed.

3.3. Procedure.

The participants will fill out a consent form before the experiment starts. The investigation will be divided into two parts. The first part is the "Writing & Remembering" section, and the second is the "Retrieving & Responding" section. In the first part of the study, List 1, which was mentioned before, will be visually presented to the participants individually. The participants would have 10 seconds for each character to write down with their dominant hand and remember it. In the second part, 10 minutes after the first part is finished, List 2 will be visually presented to the participants. The experimenter will ask the participants to make a judgment of whether they have seen the characters in List 1 one by one by simply asking them to say “old” (seen in List 1) or “new” (not seen in List 1). The participants will also be provided a squeezing ball and asked by the experimenters to squeeze the ball during all testing times constantly. In presenting the first 60 characters of List 2, the participants will be asked to squeeze the ball with their left hand. In the period of giving the second half of List 2, the participants will switch the squeezing ball to their right hand and continue squeezing it.

3.4. Variables.

The independent variable would be whether the participants will be squeezing the ball with their dominant hand, which is a categorical variable that has two levels (YES & NO); the dependent variable is the efficiency of memory encoding, which will be measured by the correct rate and the reaction time of the participant's response in the "Retrieving & Responding" section.

3.5. Predictions.

If H1 is correct (i.e., if your memory for the characters that you encoded via writing involves a motor simulation, as predicted by the embodied simulation hypothesis), then in right-handers memory should be impaired for test items they encounter while squeezing the ball with their right hand, compared to things they discover while squeezing the ball with the left hand; their ability to correctly respond "old" should be slower and less accurate when they're embracing the ball with the same hand they used to copy the character. (Figure 1) By contrast, in P0, if H0 is correct (i.e., if your memory for the characters that you encoded via writing does not involve a motor simulation), then in right-handed participants’ memory and left-handed participants’ memory, there should be no significant differences in their squeezing balls with the right hand or the left hand. Their ability to correctly respond "old" should be the same as squeezing the ball with the same hand they used to copy the character. In other words, that means proper ball squeeze should have the same effects on both the use of right-handed and left-handed and left-ball squeeze should also have the same impact on both groups.

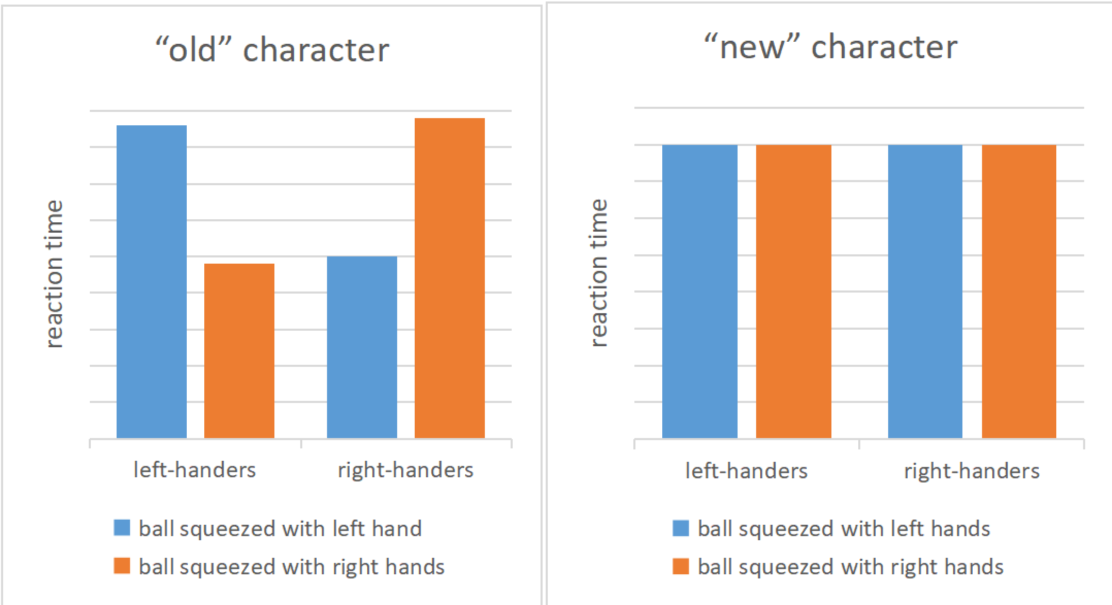

Figure 1. Predictions of the proposed study. Left: predictions under the "old" characters condition; Right: predictions under the "new" character condition (owner- draw).

4. IMPLICATIONS AND FUTURE STUDIES

Suppose the results of the proposed study support our hypothesis that memorizing a character via writing causes memory for that character to depend, at least in part, on the relevant portion (dominant hand) of the motor system. In that case, this outcome will provide strong evidence for the embodied simulation hypothesis. Also, because our proposal focuses on the embodied simulation in memory processing instead of language processing that the embodied simulation hypothesis suggests, the success of our proposal may be applied in the field of memory. Depending on the motor simulation in mind, perhaps the result of memory can lead to some reflections and further explorations on how memory is encoded and retrieved.

Further studies using other aspects of the motor system than handedness would be needed to provide solid evidence for the hypothesis that memory depends at least partly on motor simulation. Besides, possible clinical implications of treating memory-related disorders may be discovered if the proposed study is confirmed and replicated successfully by enough further studies.

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