Aging and posture in the Memory of Manipulable Objects

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Abstract

Thirty healthy elderly participants (mean age = 77.3) learned the names of manipulable and nonmanipulable objects while adopting a control posture (hands in front of them) or an interfering posture (holding their hands behind their back). Results on a recall task showed a postural interference (PI) effect, with the interfering posture reducing the memory of manipulable objects, but not of nonmanipulable ones. The effect was similar to the Postural Interference effect previously observed in young adults, although with a lower performance. These results call into question the embodied theory hypothesis that the deterioration of memory in aging is related to the decline of the sensorimotor system.

Keywords: Grounded cognition; Long Term Memory; Action; Aging; Concept

1 Introduction

One of the main claims of embodied and grounded cognition is that cognition is grounded on sensorimotor experience, i.e., that cognition shares processing resources with sensorimotor systems. During aging, the overall sensorimotor abilities of individuals slowly decrease. Aging is therefore an ideal candidate to test the claim of embodied cognition (Vallet, 2015). The hypothesis is that as the sensorimotor system declines, the embodiment of cognition also moves in the same direction. Among cognitive functions, studies over the last few decades have found that memory decreases over time in older people (e.g., Danckert & Craik, 2013). If sensorimotor systems contribute in memory, its deterioration with aging might be due to the decline of the sensorimotor system itself. More specifically, as the sensorimotor decline mainly concerns the motor system, motor related memory should be especially affected by aging. The aim of this paper was to investigate this issue.

According to grounded cognition, memory shares processing resources with sensorimotor systems. In this view, memory retrieval consists in the reinstatement of the sensorimotor activity at encoding, a sensorimotor simulation which allows access to the content of the memory trace. Some evidence for this idea comes from studies on conceptual processing (for a review, see de Vega, 2012). Many studies have shown for instance that the processing of concepts of manipulable objects triggers a motor reinstatement of the action related to the object (e.g., Bub, Masson, & Cree, 2008; Tucker & Ellis, 2004). Tucker and Ellis (2004) showed, for example, that reading a word denoting an object which could be grasped with a precision or a whole-hand grip speeded up the response requiring a similar grip. This suggests that the reading of an object word provokes a motor simulation of the related action, which facilitates the subsequent execution of the action. It has been suggested however that this kind of activation could be the mere consequence of a cascade of activations, without actually participating in the content of the concept (Mahon & Caramazza, 2008). In response to this criticism, some researchers have attempted to interfere with the motor simulation to assess its functional role in conceptual processing. Along these lines, Dutriaux and Gyselinck (2016) asked their participants to memorize lists of names of manipulable and nonmanipulable objects while adopting different postures. In the control condition, they had to put their hands in front of them, at rest, and in the interfering condition, they had to keep their hands behind their back. Results showed a Postural Interference effect (PI effect), i.e., when the posture does not favor action as in the interfering condition, the recall of manipulable objects – and not of nonmanipulable objects – was lower than in the control condition. This Postural Interference effect suggests that the posture interfered with the motor simulation related to manipulable objects, which resulted in an impairment of the memory for these objects. These results clearly show that memory shares processing resources with motor systems (see also Dutriaux, Dahiez, & Gyselinck, 2019).

If this claim is correct, a lesion of the motor system should also disrupt motor related memory. Several studies are consistent with this idea. For instance, patients suffering from apraxia are slower in lexical decision tasks when presented with the names of manipulable objects than controls, but not when presented with the names of nonmanipulable objects (Desai, Herter, Riccardi, Rorden, & Fridriksson, 2015). They also have a deficit of knowledge about the functions of tools (Buxbaum & Saffran, 2002; Myung et al., 2010). Previous research has shown that aging can also have a negative impact on motor functions (for review, see Seidler et al., 2011). For instance, while pointing movements were performed similarly in younger and older adults when only an extension of the elbow was required, older adults were less smooth and precise when pointing required to coordinate both elbow extension and horizontal elbow flexion (Seidler, Alberts, & Stelmach, 2002). It shows that older adults demonstrate deficits in performing actions requiring coordination in multiple joints. In the same vein, the duration of fine motor movements increases with age in individuals older than

60 years, but not in those younger than 60 years (Smith et al., 1999). This reduced performance might be explained in part by a reduction of brain volume. For instance, it has been found that, from middle age, the cortical mantle becomes thinner in different regions of the brains, the primary motor cortex being the most affected of these regions (Salat et al., 2004). It suggests that older people might demonstrate similar motor related memory deficits (although reduced) as in the lesion studies, although not as severe as after actual brain lesions. Studying aging can thus be considered as another mean to investigate the effect of motor disruption on the embodiment of memory (Costello & Bloesch, 2017; Vallet, 2015). Given that aging induces a motor decline, it might be that this decline feeds through to motor simulation. This idea is supported by the literature on mental imagery, which can be considered as a form of conscious sensorimotor simulation. Several studies have shown a stronger deterioration in visual and motor imagery in the third-person perspective (e.g., imagining someone else performing an action) with aging, compared to first-person imagery (e.g., imagining an action performed by oneself). As first-person imagery requires more somatomotor inputs, this deterioration might be taken as a sign of the effect of motor decline on motor simulation (see Costello & Bloesch, 2017). Another function impaired with aging is the ability to overtly simulate movements with pantomimes, this deficit being even more pronounced for pantomimes involving a tool (e.g., Mozaz, Crucian, & Heilman, 2009).

Altogether, these studies suggest that motor simulation might be adversely affected by aging. If motor related memory retrieval relies on the motor reenactment of past experiences, this memory should also decrease in older people. To our knowledge, only one study directly addressed this question. Dijkstra, Kaschak, and Zwaan (2007) showed that when participants are asked to remember autobiographical episodes, memories are recalled faster when participants have a posture congruent to the recalled memory (e.g., lying down while recalling their first visit to a dentist). Interestingly, this effect appeared to be smaller for older adults than for young adults, suggesting that the posture primes the related memories, but that the impairment of motor systems in older adults weakens this link. The present work aimed to assess if the impairment of motor systems also reduces an interfering effect of posture (the Postural Interference effect) on the memory of words by replicating the study of Dutriaux and Gyselinck (2016) with elderly adults. Just as in the original study, participants had to learn lists of manipulable and nonmanipulable objects while keeping their hands either in front of them (control posture), or behind their back (interfering posture). If motor simulation is impaired in older adults, then, contrary to young adults, no Postural Interference effect should be observed. The posture should not have any effect on the memory of nonmanipulable objects or on the memory of manipulable objects, since, if the motor simulation is disrupted, there is nothing for the posture to interfere with. There is however some evidence that elderly adults rely more on sensorimotor information than younger adults to understand language (Dijkstra, Yaxley, Madden, & Zwaan, 2004). In this study, participants had to read sentences (e.g., "The ranger saw the eagle in the sky") about objects and were then shown a picture of an object that either matched (an eagle with its wings outstretched) or mismatched (an eagle with its wings folded) the suggested shape of the object in the sentence. Responses were faster in the shape-matching condition for all participants, which shows that reading involves a sensorimotor simulation that facilitates the processing of the matching pictures. Importantly however, this mismatch effect was stronger for older than for younger adults, suggesting a stronger effect of sensorimotor simulation with aging. If this is the case, then, the Postural Interference effect should still be observed or even increased in older adults.

2 Method

This study conforms to the ethics norms of human research of the University of Paris, and as a non interventional study is not subject to an ethics committee approval. As this study is a replication attempt with older adults in order to investigate the hypothesis of a reduced motor simulation with aging, the above-described method is identical (with the exception of the testing location) to the method used in Dutriaux and Gyselinck (2016).

2.1 Participants

Thirty healthy right-handed elderly adults were recruited through public announcement. The mean age was 77.30 years (17 women, SD = 53.94, range = 67-90 years). The Mini Mental State Examination (MMSE; Folstein, Folstein, & McHugh, 1975) and the Geriatric Depression Scale (GDS; Yesavage et al., 1983) were administered, and participants with an MMSE score lower than the fifth percentile or with a GDS score higher than ¼ were excluded. No upper limb motor complaints were reported by the participants. The participants had no history of medical or psychiatric disorder and none of them were taking psychoactive medication affecting the central nervous system at the time of the study. All participants gave their informed consent to the experimental procedure.

2.2 Material

The task was programmed in Python 3 using the Neuropsydia package (Makowski & Dutriaux, 2017). The names of 36 manipulable objects (i.e., tools, e.g., pen, hammer), and 36 nonmanipulable objects (e.g., carpet, antenna) were distributed in six lists of 12 words (for the wordlists, see Supplementary Material). They did not differ in word length ($t < 1$), objective ($t(70) = 1.68$, p = .10) or subjective ($t(70) = 1.56$, p = .12) frequencies, or imageability ($t(70) = 1.30$, p = .20). Objective frequency means were computed with the LEXIQUE database (New, Pallier, Ferrand, & Matos, 2001), and the subjective frequency and imageability means were computed with a combination of three norms (Bonin, Méot, Ferrand,

& Roux, 2011; Desrochers & Bergerons, 2000; Desrochers & Thompson, 2009). Each list contained the names of six manipulable objects and six nonmanipulable ones. Words were presented on a grey background (arial 100) in the center of the screen.

2.3 Procedure and design

Participants were tested individually in a quiet room with the experimenter present. Each list was presented, then followed by a distractive task and an oral free recall. During the study phase, words were presented one by one on a computer screen during 1 s, with an inter stimulus interval of 500 ms. Participants were instructed to memorize the items. Before each list, they were asked to adopt the control or the interfering posture. The control posture required putting their hands in front of them, at rest, and they were told that they could move their hands if necessary (e.g., to scratch their nose). The interfering posture required keeping their hands behind their back, holding one of their wrists with the other hand. The six lists were presented randomly, as were the 12 words within each list. The participants were presented with a block of three lists in the control condition, and three lists in the interfering condition. The order of the blocks was counterbalanced across participants. After each list, participants had then to perform the distractive task adopting the control condition. The distractive task was introduced to test long-term memory, and lasted 1 min. In this task, pairs of letters, one lower-case and one upper-case, were presented during 1.5 s, and the participants had to say whether the letters were the same (e.g., “A”, “a”) or different (e.g., “B”, “a”). Finally, the participants had to recall orally the words of the previously presented list, until they indicated that they had nothing left to recall. Participants performed the recall task with their hands in front of them in both learning conditions.

3 Results

Figure 1 shows the mean proportion of words correctly recalled. The data from the present experiments are publicly available at the Open Science Framework website (https://osf.io/kpvft/). They were analyzed using a 2 x 2 repeated measure ANOVA, with manipulability and posture as within-subject variables. First, the results showed no main effect of posture ($F(1,29) = 3.16$, $p = .09$, $MSe = 0.006$, $\eta^2_p = .10$), or manipulability ($F < 1$). Crucially, a two-way interaction coherent with a Postural Interference effect was found significant ($F(1,29) = 12.42$, $p < .01$, $MSe = 0.007$, $\eta^2_p = .30$). The planned comparisons revealed that the interfering posture decreased the memory of manipulable objects ($F(1,29) = 22.52$, $p < .001$, $MSe = 0.004$, $\eta^2_p = .44$), but not of nonmanipulable objects ($F(1,29) = 1.48$, $p = .23$, $MSe = 0.010$, $\eta^2_p = .05$).

Furthermore, to compare the Postural Interference effect observed in old and young adults, a complementary analysis including the present results and the results from Dutriaux and Gyselinck (2016) was run (26 women, 8 men, mean age = 22.26 years, SD = 6.63). For this purpose, a 2 x 2 x 2 repeated measure ANOVA was used, with manipulability and posture as within-subject variables, and age group as a between subject variable. This analysis showed a main effect of age ($F(1,62) = 43.15$, $p < .001$, $MSe = 0.040$, $\eta^2_p = .41$), that is, the recall performance was higher for young than for old adults. While the interaction corresponding to the Postural Interference effect was still significant ($F(1,62) = 13.97$, $p < .001$, $MSe = 0.010$, $\eta^2_p = .18$), no interaction between the age groups and the other factors was observed (*F*s < 1), which suggests that the Postural Interference effect was similar in both groups.

*** Insert Figure 1 here ***

4 Discussion

This experiment aimed to assess the effect of the deterioration of motor skills related to aging on motor simulation. To that end, the present protocol followed closely the one used by Dutriaux and Gyselinck (2016). The participants had to learn lists of manipulable and nonmanipulable objects while keeping their hands either in front of them (control posture), or behind their back (interfering posture). The results showed a Postural Interference effect for older adults similar to what was observed in the study by Dutriaux and Gyselinck with young adults. Compared with the control posture, the interfering posture decreased the recall of manipulable objects, but not of nonmanipulable objects.

Importantly, these results replicate those of Dutriaux and Gyselinck, showing again that memory depends on the bodily state, and thus that memory shares processing resources with the sensorimotor system. However, contrary to our main hypothesis (Costello & Bloesch, 2017), despite the decay of the motor system due to aging, the Postural Interference effect was not suppressed or diminished. This suggests that the motor simulation mechanism was well preserved in the older adults considered in this study. This result is consistent with the alternative hypothesis derived from the results of Dijkstra et al. (2004). They suggest that older adults rely more on sensorimotor information than younger adults. Consistently in the present experiment, the magnitude of the Postural Interference effect is descriptively larger with older than younger adults. Besides, Dijkstra et al. (2007) found that the effect of posture on memories was smaller with the elderly group than the young adults group, but this effect concerned only response time, and not retrieval performance in itself. One possibility is that the effect of the decline of the motor system in elderly adults might not be strong enough to affect performance such as free recall scores. Another explanation lies in the material used. The main deficit observed in terms of manipulation in aging concerns fine motor skills (Smith et al., 1999), while roughly half of the objects presented in this study do not require fine motor movements. The results might have been different if only tools involving fine movements had been used. A complementary analysis was thus run by removing the objects involving fine motor skills from the analysis, and the same pattern of results as with the complete lists of objects was found. It suggests that this explanation does not hold in this case.

As stated in the introduction, the hands behind the back would interfere with motor simulation, which would decrease the related memory. There are different reasons why such a posture should affect motor simulation. First, embodied simulation is situated, which means that it depends on the context (Yee & Thompson-Schill, 2016). For instance, when an action verb referring to an object visible in the environment is processed, the motor activation related to the processing of the action verb is stronger when the object is reachable than when it is not (Ambrosini, Scorolli, Borghi, & Costantini, 2012; Costantini, Ambrosini, Tieri, Sinigaglia, & Committeri, 2010). In the present experiment, the motor simulation related to the object might decrease following the same idea, because the context does not favor action. Second, there is evidence showing that posture affect motor imagery performance (Funk, Brugger, & Wilkening, 2005; Ionta, Fourkas, Fiorio, & Aglioti, 2007; Lorey et al., 2009; Sirigu & Duhamel, 2001). In particular, Sirigu and Duhamel have shown that putting the hands behind ones back has a detrimental effect on motor imagery response times. Consistently with these findings, a posture that is incompatible with the action to be imagined decreases the motor excitability of the motor cortex (Vargas et al., 2004). Third, our recent work using EEG have shown that putting the hands behind the back not only decreases sensorimotor simulation during action sentences reading (de Vega, Moreno, García-Marco, Dutriaux, & Gyselinck, 2019), but also during the subsequent recall of these sentences, even though the recall is performed with the hands in front (Dutriaux et al., 2019). Again, this points out that the hands behind the back interfere with motor simulation, which has a negative impact on memory.

To sum up, this work confirms once again the existence of a Postural Interference effect: an interfering posture - hands behind the back - interferes with the memory of manipulable objects, but not of nonmanipulable objects. This effect shows that memory is grounded on sensorimotor systems, i.e., that memory shares processing resources with those systems. Importantly, these results suggest that this grounding is well preserved in older adults, and that the effect of aging on memory may not result from the decline of sensorimotor systems.

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Figure 1: Means for the proportion of items recalled as a function of manipulation and posture in old adults as compared to the young adult sample from Dutriaux and Gyseslinck (2016). Error bars represent standard errors of the mean.