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► **To cite this version:**

Badiâa Bouazzaoui, Lucie Angel, Ilona Moutoussamy, Jérémy Villatte, Michel Isingrini, et al.. Kinematic observation reduces effect of aging on episodic memory performance. *Acta Psychologica*, 2024, 243, pp.104130. 10.1016/j.actpsy.2024.104130 . hal-04399781

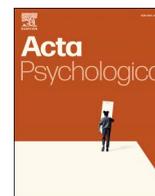
HAL Id: hal-04399781

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Submitted on 17 Jan 2024

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Kinematic observation reduces effect of aging on episodic memory performance

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ARTICLE INFO

Keywords:

Episodic memory
Action verb processing
Point-light display
Kinematics
Aging

ABSTRACT

This study investigated the influence of kinematics observation (i.e., observing action from only the motion of the main joints of an actor) on episodic memory performance differences between young and older adults. To this end, 42 young (20–35 years) and 45 older (60–75 years) participants performed a free recall task in two different conditions: either after an encoding phase consisting of the visual presentation and reading of action verbs or after an encoding phase consisting of the visual presentation and naming of point-light displays of humans performing the same actions. Results showed a beneficial effect of point-light display encoding for both young and older participants but with a more pronounced benefit for the older participants compared to young adults. These findings are discussed in relation to the embodied view of memory which considers that memory is directly linked to the sensorimotor experiences and the environmental support hypothesis which postulates that elaborate processing can improve memory performance. In conclusion, kinematic observation could constitute an interesting potential intervention for supporting memory in older adults.

1. Introduction

Memorizing past events and being able to restore them is one of the most important functions in humans. Many studies have focused on the mechanisms underlying episodic memory across the lifespan. However, the links that might exist between episodic memory and perception of kinematics have been little investigated to date. Numerous studies have shown that the ability to observe and to interpret biological actions through observation is one of the most robust skills in humans (Pavlova, 2012). The term *biological motion* was coined by Johansson more than 40 years ago in the context of the point-light display (PLD), representing only the kinematics of the head and the main joints of the body (i.e., shoulders, elbows, wrists, hips, knees and ankles) during the production of an action (Johansson, 1973). Johansson demonstrated the high sensitivity of humans to PLDs, indicating that kinematics alone can inform movement recognition (Johansson, 1973, 1975, 1976).

Interestingly, this sensitivity to biological motion is thought to be present from birth (Bardi et al., 2011; Bidet-Ildei et al., 2014; Simion et al., 2008; Simion et al., 2011), and is well preserved in older people (Norman et al., 2004; Spencer et al., 2016). More recently, in accordance

with the embodied view of cognition, which suggests that cognition is based on sensorimotor experiences (Barsalou, 1999; Coello & Fischer, 2016), several authors have studied the importance of kinematics in cognitive performances. For example, the observation of PLDs of human movements has been shown to facilitate the performance of semantic recognition tasks featuring verbs (Beauprez & Bidet-Ildei, 2017) suggesting that action observation and action language processing rely on the activation of common sensorimotor representations (Bidet-Ildei, Beauprez, & Badets, 2020; Bidet-Ildei & Toussaint, 2015). However, the link between action observation and action verb processing seem dependent of the age of the participants (Bidet-Ildei, Beauprez, & Boucard, 2020; Bidet-Ildei et al., 2022). Actually, when young and older participants have to judge whether an image contains a human after listening to an action verb, the results showed that younger people were faster to detect the presence of a human in the image in congruent conditions (i.e., namely when the action verb and the image refer to the same action) whereas this effect was not present in older adults' participants suggesting that sensorimotor activation related to action verb processing decreases with age (Bidet-Ildei, Beauprez, & Boucard, 2020).

Following the idea that kinematics could affect cognition (Beauprez

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& Bidet-Ildei, 2017), Villatte et al. (2023) explored the effect of kinematic observation on episodic memory, the memory system that allows for conscious recollection of personal happenings and events from the past (Wheeler et al., 1997). These authors showed that the implicit encoding of PLDs representing actions generates better recall of the corresponding action verbs than the implicit encoding of visually presented definitions. Interestingly, this effect disappeared when the PLDs were associated with abnormal nonbiological kinematics, indicating that biological kinematics are important for memory performance (Villatte et al., 2023). These results accord with the embodied conception of memory, which assumes that memory encoding is based on sensorimotor experiences (Briglia et al., 2018; Vallet, 2015; Versace et al., 2014). Actually, kinematics observation involves sensorimotor activation (Saygin et al., 2004; Ulloa & Pineda, 2007), so, it appears logical that encoding through kinematics observation could improve the strength of memory traces (i.e., by increasing the amount of sensorimotor information available) and thereby facilitate memory retrieval (Villatte et al., 2023).

Taken together, these studies suggest that kinematics is involved in cognition, notably by improving the processing of action verbs and the memorization of actions. However, to our knowledge, the effect of kinematics observation on memory has only been tested in young adults and have not been studied at all in the elderly, and this is therefore the aim of the present research. Older adults are an interesting experimental group to investigate the effect of kinematics observation on memory because, on the one hand, sensorimotor activation related to action verb processing seems to decrease with age (Bidet-Ildei, Beauprez, & Boucard, 2020) and, on the other hand we know that cognitive performance, particularly memory, declines as people grow older (Anderson & Craik, 2000; McDaniel et al., 2008). As sensorimotor processing is more activated with kinematics observation than with action verb processing (Villatte et al., 2023) kinematics observation would improve memory in older adults reducing in turn aged-related effect on memory performance.

Then in the present study we aimed to explore the potential benefit of kinematics observation in older adults by comparing the memory performances of young and older participants on a free recall task where the explicit encoding involved either words or PLDs representing human actions. We hypothesized that kinematics would improve memory performance in older adults as it has been shown to do in young adults (Villatte et al., 2023). Moreover, given that older adults have more difficulty activating sensorimotor representations from the presentation of action verbs (Bidet-Ildei, Beauprez, & Boucard, 2020), we postulated that kinematics observation would be more beneficial for older adults.

2. Method

2.1. Participants

Our target sample size was determined using an a priori power analysis (G*Power, Faul et al., 2007). As this study is new to the field, we estimated our sample size based on two studies, one reporting an effect of age on free recall with a *d* of 0.86 (Bouazzaoui et al., 2022), and another reporting an effect of condition (word vs. PLD in young adults,

Villatte et al., 2023) with a *d* of 1.06. Our 2 × 2 design could achieve 80 % power with as few as 31–45 participants. We decided to exceed these criteria and recruited 87 participants.

The sample consisted of 42 young (20–35 years) and 45 older (60–75 years) native French speakers recruited from the general population. They were randomly assigned to either the word or the PLD condition. The characteristics of participants in each group are summarized in Table 1. Older adults generally have a lower level of education than younger adults. This effect could be due to the evolution of the society with a more proportional of population who made graduate studies (69 % of 25–34-year-olds) have a high school diploma compared to only 37 % of 55–64-year olds according to INSEE (Niveau d'éducation de La Population – France, Portrait Social | Insee, 2019). Thus, as in most studies exploring memory function in aging (i.e., Bouazzaoui et al., 2022; Burger et al., 2017), we assessed vocabulary level (Mill Hill Vocabulary Scale; Deltour, 1993) to ensure that the vocabulary level of older adults was not lower than that of younger adults, thus guaranteeing a certain equivalence of cultural knowledge between young and older adults. Finally, as we are interested by the normal evolution of memory with age, we controlled that none of the participants declared having a history of brain injury, cardiovascular disease, psychiatric disease or alcoholism, and all had normal or corrected-to-normal eyesight. None of them were taking medication known to affect the central nervous system. Moreover, as anxiety may impact memory functioning, we checked with usual scale that all the participants scored below the recommended cut-off of 11 on the two subscales of the Hospital Anxiety and Depression Scale (Zigmond & Snaith, 1983). The Mini-Mental State Examination (Folstein et al., 1975) was administered to all older adults to exclude participants with a pathological cognitive impairment. All of them scored above the standard cut-off of 27, suggesting that they did not have any cognitive disorder. The study was approved by the local ethics committee of Tours University (CER-TP 2022-02-06), and all participants took part on a voluntary basis and signed an informed consent form.

2.2. Material and procedure

During a single session with the experimenter (see Fig. 1), participants completed a set of screening measures (Mill Hill Vocabulary Scale, Hospital Anxiety and Depression Scale, Mini-Mental State Examination), followed by an episodic free-recall task. Participants were seated in a chair in front of a laptop computer placed on a table at a distance of 50 cm. The experiment was developed using E-Prime 3.0 software (Psychology Software Tools, Pittsburgh, PA). The material consisted of 25 French action verbs presented in one of two formats, depending on the experimental condition: either words (e.g., “To run”, “To applaud”, “To jump”) or PLDs of the relevant human movements, performed by a young man (for a list, see Appendix 1), extracted from the PLAViMoP online database (<https://plavimop.prd.fr/en/motions>). We proposed to use the PLD methodology because it assured that actions were only represent by kinematics without the presence of other information (e.g., the context, the body of the actor, etc.). We chose to work with 25 actions which can be easily recognizable and described with a single verb. The number of 25 ensures that the task was sufficiently difficult to avoid

Table 1
Characteristics of participants per group and experimental condition (means and standard deviations).

	Young		Older		Age <i>F</i> (1, 83)	Condition <i>F</i> (1, 83)	Age × Condition <i>F</i> (1, 83)
	Word (n = 21)	PLD (n = 21)	Word (n = 23)	PLD (n = 22)			
	<i>M</i> (<i>SD</i>)						
Age	24.80 (4.47)	23.71 (3.46)	66.86 (3.58)	65.63 (3.51)		2.07, <i>p</i> = .15	0.01, <i>p</i> = .93
% of females	58	41	44	55			
Education	14.85 (1.06)	15.19 (0.81)	12.30 (2.42)	12.81 (1.84)	46.25, <i>p</i> < .001 $\eta^2 p = 0.35$	2.11, <i>p</i> = .15	0.33, <i>p</i> = .56
Vocabulary (Mill Hill)	25.47 (2.82)	24.61 (2.33)	25.78 (2.37)	26.54 (2.66)	4.14, <i>p</i> < .05 $\eta^2 p = 0.04$	0.007, <i>p</i> = .93	2.18, <i>p</i> = .14

Note. *M* = Mean, *SD* = Standard Deviation, *n* = sample size.

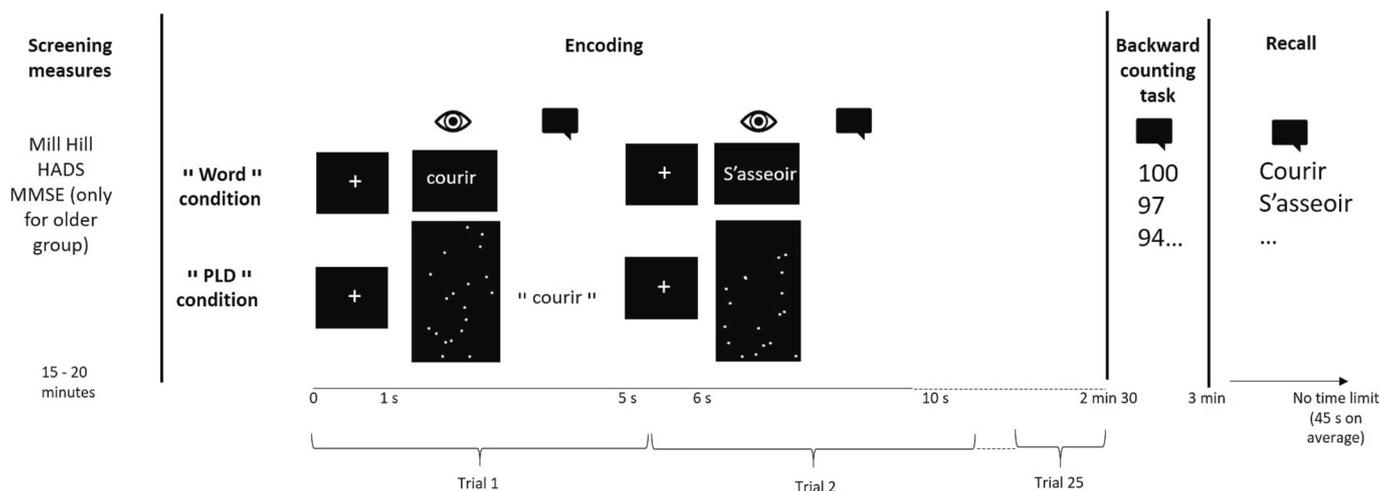


Fig. 1. Description of procedure for each participant.

a ceiling effect and not too hard to conserve the motivation of participants. All the PLDs featured 19 animated dots representing the actor's head, left and right shoulders, left and right elbows, left and right wrists, left and right fingers, left and right hips, left and right knees, left and right ankles, left and right heels and left and right toes. Participants were instructed either to read out the actions (word condition) or to name the actions (PLD condition), in order to memorize them for a subsequent free-recall test. The encoding phase started with a 1000-ms presentation of a fixation cross, followed by a word or a video of Point Light presented for 4000 ms. The words and PLDs were shown in white against a black background and were presented in a random order. After the encoding phase, participants performed a 30-s backward counting task in steps of three, to reduce the recency effect. Actually, the interference task blocks the natural capacity of humans to conserve the last items in short-term memory (Baddeley, 1968). They were then asked to say aloud all the actions they could remember, with no time limit. In the PLD condition, the recall was deemed to be correct if the participant's response corresponded to the name given by the participant for the PLD in the encoding phase. Participants first carried out a familiarization phase with a short block of eight items. This familiarization phase was important for the PLD condition, which was unfamiliar to the participants. It also ensured that all participants understood the instructions. The 8 items used in this phase were different from those used in the test phase. All participants performed the task in a quiet room with only the experimenter.

2.3. Data processing

Analyses were conducted using Statistica 13 software (TIBCO Statistica®). First, we conducted statistical analyses on groups characteristics. A χ^2 test examined the gender distribution across age groups (young vs. older) and conditions (word vs. PLD). Analyses of variance were conducted to test effects of age group and condition on age, education level (in years) and vocabulary. Secondly, to test our main hypothesis we ran a factorial analysis of variance with age group and condition as between-subjects factors on the proportions of correctly recalled items.

3. Results

The characteristics of participants are presented in Table 1. The proportion of females was equivalent across age groups and conditions, $\chi^2(4) = 2.84, p = .58$. Regarding age, apart from the significant effect of age group, there were no effects of either condition or the interaction between the two. The same pattern of results was found for education

level, with results indicating an effect of age group, such that young adults had a higher education level than older adults and no effects of either condition or the interaction between the two. For vocabulary, we again observed an effect of age group but no effects of either condition or the interaction between the two, confirming that despite their lower education level, older adults had greater cultural knowledge.

On memory performance, results (see Fig. 2) revealed that young participants recalled significantly more items than the older (Mean young = 53 %, SD young = 11 %; Mean older = 41 %, SD older = 13 %, $F(1, 83) = 41.03, p < .001, \eta^2 p = 0.33$) and that recall was greater in the PLD condition than in the word condition (Mean PLD = 56 %, SD PLD = 08 %; Mean word = 38.5 %, SD word = 12 %, $F(1, 83) = 89.81, p < .001, \eta^2 p = .59$). Finally, we obtained a significant Age group \times Condition interaction, ($F(1, 83) = 8.86, p < .01, \eta^2 p = .09$), indicating that the difference between young and older participants was greater in word condition (17 %, $F(1, 83) = 44.50, p < .001$) than in PLD condition (6 %, $F(1, 83) = 5.81, p < .05$) suggesting that PLD could sustain the memory performance in aging. Moreover, PLD is more beneficial for older adults (23 % of improvement, $F(1, 83) = 80.31, p < .001$) than for younger participants (12 % of improvement, $F(1, 83) = 20.42, p < .001$) which could suggest that sensorimotor system would be less evoked in older people when they have to memorize action verbs through reading.

4. Discussion

The aim of the present study was to assess the role of kinematics in memory performance among older people, testing the hypothesis that it improves episodic memory performance by increasing the amount of sensorimotor information available. To this end, we compared the action verb recall performances of young and older participants under two different encoding conditions: observing and reading the words versus observing and naming PLDs representing the actions. Results showed that the observation of PLDs improved episodic memory performance in both groups. Interestingly this beneficial effect was greater in older participants, reducing the effect of aging on memory. To support our findings, and because the a priori power analysis was based on studies that did not test the interaction between age and condition tested in the present study, we also calculated post hoc power (G*Power, Faul et al., 2007) and our sample size ($N = 87$) achieved 81.5 % of power.

In young adults, our findings confirmed the role of kinematics observation in cognition (Badets et al., 2015; Beauprez & Bidet-Ildei, 2017, 2018), and more particularly in the recall of action verbs (Villatte et al., 2023). Observing PLDs of human actions improves young people's memory performance, whether the encoding is implicit (Villatte et al., 2023) or explicit (the present study). Moreover, we demonstrated

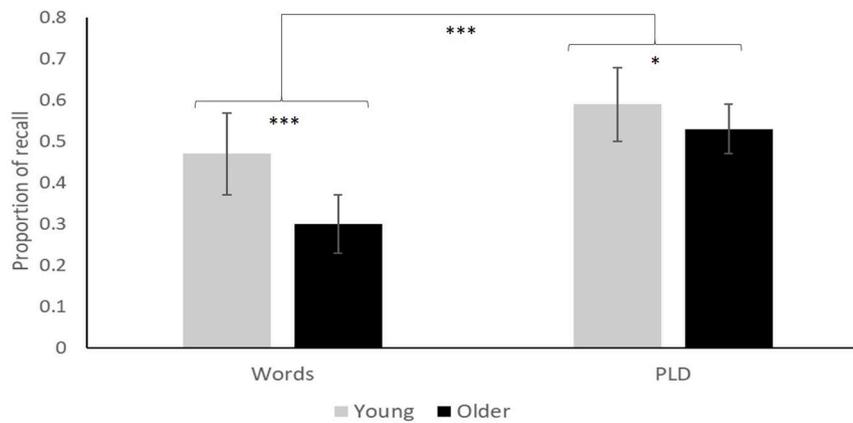


Fig. 2. Proportions of correctly recalled items according to age group and condition. Error bars represent standard errors. * $p < .05$. *** $p < .001$.

for the first time that kinematics observation is beneficial for the memory performance of older people, suggesting an embodied conception of memory (Briglia et al., 2018; Versace et al., 2014) whereby sensorimotor information is crucial to memory performance, and can explain the memory performance of both young and older people. The superiority of the PLD condition over the word condition can be explained by the theory of embodied cognition and more particularly by the motor simulation of action (Villatte et al., 2023). With kinematics, the observation of the action increases the amount of sensorimotor information available, which in turn strengthens the memory trace and thus enhances memory retrieval. However, it is important to bear in mind that several studies have shown that the reading of action verbs automatically activates the associated sensorimotor representations (see Bidet-Ildei, Beauprez, & Badets, 2020, for a review). We can therefore assume that the action verb and sensorimotor representation were activated in both encoding conditions. However, performances were still better with PLD encoding. This difference can be attributed to greater activation of sensorimotor representations through kinematics than through words, suggesting that the link between action observation and action language processing is asymmetric. Action verbs may be automatically activated when humans observe kinematics, whereas the processing of words may not necessarily be associated with the activation of kinematic features. Therefore, we can hypothesize that the activation of sensorimotor representations is not systematic or else is less precise in older people than in young ones when they read action verbs. This could explain why the effect of aging on memory performance is greater for the encoding of words (which appear not to activate sensorimotor representations in older individuals) than of PLDs in line with recent findings which show that the activation of sensorimotor representations during action verb processing decreases with age (Bidet-Ildei, Beauprez, & Boucard, 2020). Moreover, our result argues for the possibility to activate sensorimotor system in older adults under certain conditions (Mille et al., 2021).

Two other theories, the dual coding theory (Paivio, 2014) and the depth of processing theory (Craik & Lockhart, 1972), could also be used to interpret the results obtained and at the same time raise a potential limitation of the study. Indeed, the format in which the action was presented in the PLD condition made the image and verb easier to process than they were in the word condition. Also, according the level of processing theory (Craik & Lockhart, 1972), whereby memory performance depends on the level at which information has been processed at encoding: the deeper the processing, the stronger the memory trace. The generation effect (Slamecka & Graf, 1978) is a good illustration of this theory. In this paradigm, participants classically either have to read word pairs (e.g., saddle-horse) or else generate a semantic associate from letter cues (e.g., garden-fl—) for subsequent cued recall. Studies using this paradigm have shown that stimuli produced during encoding are recalled better than stimuli that are simply read (Taconnat et al.,

2003; Taconnat & Isingrini, 2004). The comparison of the two conditions used in the present study (word vs. PLD) may also illustrate the beneficial effect of generation. Compared with the word condition, the PLD condition may encourage participants to make a cognitive effort that facilitates semantic processing and thereby reinforces the memory trace. Moreover, this generation effect hypothesis is related to the environmental support hypothesis (Craik, 1990), and may therefore explain why kinematics had a greater effect in our older participants than in the younger ones. By guiding participants' processing, the PLD condition may have served as an environmental support for strategy implementation. Insofar as older adults have difficulty self-initiating strategies when no support is provided at encoding (Bouazzaoui et al., 2022; Craik & Byrd, 1982; Craik & Jennings, 1992; Craik & Lockhart, 1972; Froger et al., 2012), our older participants probably benefited more from the environmental aid (i.e., PLD condition) than the younger ones, thereby helping to reduce the effect of aging on episodic memory. However, this hypothesis, that the observed effect is also or mainly explained by a difference in task, and therefore more by dual coding and depth of processing theories than by the role of sensorimotor activation provides a less convincing account of the previous literature (Villatte et al., 2023) where biological kinematics benefit to memory performance independently of a generation effect, where encoding was implicit and therefore did not allow participants to engage in deep cognitive processing. and also, where the beneficial effect of kinematic disappeared when the PLDs were associated with abnormal nonbiological kinematics. However, this alternative interpretative hypothesis cannot be ruled out in the present study. Therefore, future research is necessary to determine whether the observed beneficial effect of PLDs in young and older adults is supported when dual coding and the generation effect are controlled.

Importantly, in a practical view, whatever the mechanism implied, the present study suggests that observing PLD is beneficial for older adults in memorizing action verbs. This result is consistent with studies that have shown that observation action leads to better recall than purely verbal tasks (Feyereisen, 2009; Zimmer et al., 2001). Our result adds important finding namely that kinematics observation seems to be sufficient to improve the encoding of action verbs and that PLD could be used as a method to sustain memory functioning in elderly. Moreover, in a theoretical point of view, the benefit obtained with only kinematic perception will render easier the assessment of the specific mechanisms implied in the positive effect of action observation in memory performance. Actually, PLD can be manipulated easily (see PLAViMoP software, Decatoire et al., 2019) and therefore are more adapted to disentangle the crucial multiple parameters of action observation benefit (biological kinematics, action recognition, attention, etc.). Using this methodology, future research would add information about the mechanisms at work, thus providing further empirical support for the mechanisms that underpin the functioning of episodic memory.

The present study had some others limitations. First, we did not assess our participants' motor level, even though it may affect the processing of kinematic information (e.g., Chary et al., 2004). Moreover, the PLDs we used represented actions produced by a young man, and it would be interesting to determine whether PLD efficiency is related to the match between participants' motor repertoire and the perceived actions (Coste et al., 2021; Martel et al., 2011). Finally, here we tested only the effect of kinematics on the memory of actions which implies the whole body of the participant and with only a recall task. Future research would assess whether the effect persists with other type of action verbs (i.e., manual or expressive verbs) and with other tasks (e.g., recognition or deferred recall). It would be also interesting to assess whether the positive impact of PLD could transfer to concrete nouns which implies specific actions such as writing or screwing.

In conclusion, the present study demonstrated that memory performance for action verbs can be improved by the observation of kinematic information at encoding. This effect was present in both young and older participants, but was stronger in the latter, suggesting that kinematic observation may be a good way to support memory performance in aging. Future studies will have to disentangle the origins of the benefit, and more particularly the role of sensorimotor skills.

CRediT authorship contribution statement

Badiâa Bouazzaoui: Conceptualization, Formal analysis, Investigation, Methodology, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing, Data curation. **Lucie Angel:** Conceptualization, Methodology, Validation, Writing – review & editing. **Iлона Moutoussamy:** Methodology, Validation, Writing – review & editing. **Jérémy Villatte:** Methodology, Validation, Writing – review & editing. **Michel Isingrini:** Conceptualization, Methodology, Validation, Writing – review & editing. **Christel Bidet-Ildei:** Conceptualization, Investigation, Methodology, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing.

Declaration of competing interest

None.

Data availability

For transparency and openness, the data are available on the Open Science Framework depository here: https://osf.io/ubm2k/?view_only=cd7260b475774bf2a32bd50450dc2af4

Appendix 1. List of the 25 PLDs and words used in the memory task. PLDs were extracted from the PLAViMoP database

PLD name	Corresponding verb in French
Acquiesce Man	Acquiescer
Applaud Man	Applaudir
Catch Man	Attraper
Crouch Man	S'accroupir
Dance Man	Danser
Decline Man	Décliner
Fall Man	Tomber
Jump Man	Sauter
Ladder Climb Man	Grimper
Ladder Get Off Man	Descendre
Move Back Man	Reculer
Pedal Man	Pédaler
Pick Up Man	Ramasser
Pull Man	Tirer
Push Somebody Man	Pousser
Put Down Man	Déposer
Run Man	Courir
Say Hello Man	Saluer
Scratch Man	Se gratter
Sit Man	S'asseoir
Stand Man	Se lever
Sweep Man	Balayer
Throw Man	Jeter
Turn Man	Tourner
Walk Man	Marcher

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