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The importance of performing versus observing meaningful actions, on the enactment benefit to memory

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ABSTRACT

Performing an action symbolic of a word during encoding aids memory for the word, relative to reading it. This subject-performed task (SPT) is known as the enactment effect. Observing an experimenter perform an action (EPT) has also been shown to aid memory, similar in magnitude to SPT. We asked whether an EPT would confer a memory benefit when the action was unrelated, and when the experimenter was not physically present, but seen in a video. Target words were presented visually one at a time. Participants enacted them, performed a non-representational gesture, or read them, depending on the encoding cue (within-subjects), or watched videos of the experimenter carrying out these tasks (between-subjects). Memory was subsequently assessed in a free-recall test. Our results show that semantic relatedness of the action to targets is critical to benefit memory, and observing others performing actions in a video attenuates the benefit conferred from meaningful actions.

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Enactment; experimenter-performed task; gestures; semantics; mirror-neurones

1. Introduction

The *enactment effect* refers to the finding that when one performs an action that depicts the meaning of a to-be-remembered target word (e.g. forming a fist and moving it across an imaginary door during encoding of the word *knock*), it benefits subsequent memory for the word, relative to simply reading the word (Verbal task) (Cohen, 1989, for review; Engelkamp & Zimmer, 1984, 1985). An important question regarding enactment is whether the action must be semantically related to the target word in order to provide a memory benefit. Gestures, which are commonly understood as spontaneous hand movements generated during a speech, are ubiquitous in our society. We use them daily to convey concrete ideas (e.g. making a fist with one hand and raising it to the shoulder to indicate lifting an object), to provide navigational directions (e.g. pointing towards a location in space), and even to communicate metaphors (e.g. gesturing upwards to suggest a high rank) (Macedonia et al., 2011). These actions were once thought to primarily aid speech comprehension between the speaker and the listener (Driskell & Radtke, 2003). However, we now know that gestures are also capable of influencing memory performance (Novack & Goldin-Meadow, 2017; Yap et al., 2011).

Past research has distinguished between different gesture or action types, based on the kind of information represented by the movement. Representational gestures, such as iconic or metaphoric gestures, are believed to reveal the meaning or the semantic content of ideas conveyed by a speaker (Novack & Goldin-Meadow, 2017; McNeill, 1992). On the other hand, non-representational or non-meaningful gestures, such as beat or deictic gestures do not convey the meaning of the accompanying speech (Novack & Goldin-Meadow, 2017; So et al., 2012). Research comparing the beneficial role of iconic to beat gestures, on memory, suggests that the semantic congruency of the gestures to target words (i.e. performance of iconic versus beat gestures) may be integral to the memory benefit that can be conferred (Kelly et al., 2009; So et al., 2012). Past studies examining the cognitive mechanism underlying the enactment effect, have suggested that the mnemonic benefit from the action during encoding relies on the level of association formed between motor and

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verbal representations (Feyereisen, 2006; Liu & Wang, 2018; Zimmer & Engelkamp, 2003). That is, a motor and a verbal memory representation must share or convey the same semantic information to generate a boost to later memorability (Macedonia et al., 2011; Zimmer & Engelkamp, 2003). These results suggest that semantic processing of the to-be-remembered information may be critical to integrate the various memory representations (motor, verbal, visual) established by an encoding technique (Pulvermüller, 2005; Meade et al., 2019; Russ et al., 2003). Previous findings from our own study also indicate that the semantic congruency of the action to the to-be-remembered word is a critical feature underlying the enactment benefit (Sivashankar & Fernandes, 2022). One goal of our current study was to replicate these findings on memory, when participants performed semantically related versus unrelated actions during encoding of action verbs (subject-performed task; SPT), and to examine whether the pattern extended to experimenter-performed tasks.

Engaging a motor component has been described as a critical factor underlying the enactment effect (Engelkamp & Zimmer, 1984, 1985). However, it is controversial whether the performer of the action is equally important to the observed memory benefit. That is, researchers have examined whether it is necessary for one to perform a representative action to a verbal target (SPT) to enhance memory, or whether it is sufficient to simply observe that action performed by an experimenter (termed *experimenter-performed task*; EPT; Cohen, 1981). Past research shows that while EPT can boost memory compared to simply reading a target word, the strength of its effect relative to SPT is variable across published studies. Some (Cohen & Bean, 1983; Cohen, 1981, 1983; Cohen et al., 1987) found no difference between the magnitude of memory benefit provided by SPT versus EPT, whereas others found a higher memory boost following SPT (Dick et al., 1989; Engelkamp & Zimmer, 1983, 1985; Zimmer & Engelkamp, 1996). The discrepancy in the findings of prior studies has been primarily linked to the order in which the encoding trials were presented. Memory is better for SPT items when lists are intermixed across EPT and SPT tasks, as opposed to when these manipulations are performed in a blocked design; as well, the type of test used to assess memory matters, with recognition tests offering better support (higher hit rate) for SPTs, and EPTs benefitting from cued and free recall (Engelkamp & Krumnacker, 1980; Engelkamp & Zimmer, 1997; Golly-Haring & Engelkamp, 2003; Koriat et al., 1991; Schult et al., 2014).

The second goal of our study was to explore the importance of social or physical presence during EPTs. This question is especially important in light of the increase in online, or remote learning, due to restrictions on physical interactions due to the Covid-19 pandemic. Research examining the importance of social interaction in online learning indicates that online learning can reduce the level of physical immediacy or social presence (e.g. measured by facial expression of the instructor, eye contact, posture, and proximity) of the instructor, and can subsequently affect student learning (Beege et al., 2020; Tseng & Morris, 2015; Woods & Baker, 2004). Thus, we sought to examine whether observing actions performed by another person, within a video presented online, was still effective in boosting memory for the target words, relative to when these are simply read aloud (verbal task), and whether the magnitude of benefit from online-viewing of an EPT was similar to that from an SPT.

Ianì and Bucciarelli (2017) argue that actions observed during EPT at encoding aid in creation of a motoric representation of the word by activating the observer's own motor system, similarly as if they were performing the actions themselves. This argument is supported by the "common coding theory" (Prinz, 1990; Hommel et al., 2001), which purports that action execution and action perception (observing the actions of others) share similar brain processing areas. It is believed that seeing an experimenter perform a representative action activates similar motor and perceptual areas in the participant via a mirror-neurone circuit (Chandrasekharan et al., 2010; Rizzolatti & Craighero, 2004; Dinstein & Behrman, 2013; Tye-Murray et al., 2013; Van der Wel et al., 2013). Mirror-neurones[1] are a particular type of visuomotor neurones that become active

[1]This class of neurons were originally discovered in the ventral pre-motor area (F5) of macaque monkeys, and have subsequently been reported in the inferior parietal lobule, including the lateral and ventral intraparietal areas, and in the dorsal premotor and primary motor cortex (Rizzolatti & Craighero, 2004). Since their original discovery, several neurophysiological evidence suggest that the human motor system also has mirror properties, such that our ability to recognize and interpret the actions of others entails the involvement of our own motor system via the mirror neuron circuit (Cochin et al., 1998, 1999; Fadiga et al., 1995).

both when an individual executes an action and when they observe a similar motor act performed by another individual (Rizzolatti & Craighero, 2004). Indeed, this notion is supported by findings from Iani and colleagues (2018), who showed the involvement of the premotor cortex in mediating the enactment benefit in participants who observed actions presented in EPTs. Further, Liew et al. (2011) found that both the familiarity of a gesture and the race of the experimenter who was performing the gesture, modulated activity in the human mirror neurone system. That is, observation of actions performed by one's same race and using familiar gestures generated stronger activation in brain areas associated with the human mirror neurone system (i.e. inferior parietal lobule, inferior frontal gyrus, motor cortices, cingulate cortex, temporoparietal junction), relative to unfamiliar gestures and actions performed by an actor who was a different race to the observer.

This finding suggests that the context in which the gestures are performed can modulate whether, and how much of, an EPT memory benefit is observed. Similarly, the lack of physical presence of the experimenter performing the action in an online EPT condition may also reduce a participant's attention to the experimenter's enactments, and/or limit mirror-neurone engagement, needed for interpretation of the observed actions. Without this, there may be a diminishing of the beneficial impact of EPT on memory (Ianì & Bucciarelli, 2017; Ianì et al., 2018).

2. Current study

We had two goals in the current study. First, we aimed to determine whether the semantic relatedness of an action to the target word influenced subsequent memory for targets. Previous work (Cohen & Otterbein, 1992; Kelly et al., 2009; So et al., 2012) examining the semantic relevance of actions to memory have used beat gestures, or actions that do not represent the target word in any way (both structurally and conceptually). In our current study, we operationalised non-representational gestures to be those in which the target words were "written in air". This type of non-representational action would not depict the semantics of the word, but the action could be mapped on to the visual word form. Although the act of writing target words in air is related to the orthography of words, the actions performed cannot be considered central to the semantics generally associated with the word. To determine whether the semantic meaning of the actions is vital for a memory benefit, we contrasted the enactment of words (hammer; make pounding action) with an action that is less habitually related to the target, writing out the target words cursively in the air. This manner of operationalising non-meaningful actions is also in line with previous studies that have defined non-representational gestures as hand movements that do not convey the semantics of the accompanying verbal commands (Cohen & Otterbein, 1992; Cook et al., 2012; Feyereisen, 2006; So et al., 2012). To this end, our current research sought to answer the question of whether actions must convey the conceptual meaning of words to confer an enactment boost, or whether it is sufficient to simply reproduce, or observe, the word form. Thus, the goal was to clarify the importance of integrating meaning to actions.

Second, we examined whether the performed action during encoding needed to be carried out by the participant to aid memory, or whether it was sufficient to simply observe a meaningful action be performed by an experimenter. There are currently mixed findings in the field regarding the magnitude of benefit gained from the performance relative to the observation of actions. Some studies have shown that observing an EPT could also confer a memory benefit that is similar in magnitude to SPT (Cohen & Bean, 1983; Cohen, 1981, 1983; Cohen et al., 1987). For example, studies in the working memory domain have shown that recall of action-object pairs was not significantly enhanced by self-enactment relative to observation (analogous to EPT; Allen et al., 2020). Those authors reasoned that self-enactment, and observation of actions performed by another, both encourage engagement of overlapping representations of motoric codes. That is, both self-enactment at encoding and observing a demonstration at encoding likely provide similar additional forms of visuospatial-motoric coding; it is this additional code that supplements the verbal code in working memory (Allen et al., 2020), accounting for the memory benefit.

Experiments conducted by Schult and colleagues (2014) support this idea, when memory was assessed using a free recall test, though it should be noted that on a recognition test for targets, SPT benefitted memory more so than EPT at encoding. Similarly, a meta-analysis by Dargue and

colleagues (2019) showed that the benefit of producing gestures (SPT) on comprehension yielded significantly larger effect sizes on average than studies investigating the effect of observing gestures (EPT) on comprehension. It is noteworthy that Dargue and colleagues (2019) did not consider in their analyses, whether the memory benefit conferred by the performance or the observation of an action was modulated by the type of retrieval test (e.g. free recall vs. forced-choice recognition). Here we asked whether EPT could still confer a benefit when the experimenter was not physically present, but seen in a video, when the retrieval test was free-recall. Thus, in our study, we examined (a) the effect of semantic relatedness of the action to target, and (b) compared the magnitude of the memory benefit, on a free recall test, in an SPT versus EPT paradigm that was conducted online and without the physical presence of any experimenter. Participants enacted, performed a non-representational gesture (write verbal targets in air), or read items, depending on the cue (within-subjects; cue type intermixed randomly), or watched videos of the experimenter carrying out these tasks (between-subjects). We predicted a main effect of encoding strategy, such that actions conveying meaningful conceptual information about target words would significantly benefit recall moreso than when words encoded using non-representational gesturing. We also predicted the magnitude of benefit would be larger following SPT than EPT observed online as physical presence of the experimenter is eliminated, and this could limit engagement of mirror neurones implicated in the previously reported EPT benefit (Ianì & Bucciarelli, 2017; Ianì et al., 2018). Further, we measured the onset time to initiate actions (i.e. response time to produce an action to a target word) in the SPT group, as an index of the level of planning required by the participant for each trial type. Ratner and Foley (1994) suggest planning of motoric tasks to be a critical component underlying the enactment effect. Since enactment of words entails conceptual processing of the word followed by the selection of a semantically related action, we predicted a longer onset time of action initiation for these trials. On the other hand, the non-representational gestures utilised in our study would entail some level of planning to select the correct movements to produce the orthographic structure of words, but not planning of an action representing the semantics of the word. Thus, we predicted the onset time of action initiation for gesturing would be shorter, relative to enactment trials.

3. Methods

3.1. Participants

After conducting a power analysis using G*Power software (version 3.1), a sample size of 36 participants or greater was deemed necessary per task (EPT and SPT) to have 90% power to detect a medium effect size ($\eta_p^2 = 0.06$) with an alpha level of 0.05 (Field, 2005).[2] We planned to remove participants who score below 30% on the Mill Hill Vocabulary Scale (MHVS) to allow us to reliably interpret variability in memory performance as a function of trial type (experimental manipulation), and not as a result of language difficulties (Raven, 1958).

Eighty-six undergraduate students from the University of Waterloo successfully participated for a partial course credit. Data from 4 participants were excluded based on their poor performance on the MHVS. The final sample included eighty-two (N = 41 for SPT, ages ranging from 17 to 23 [$M = 19.35$, $SD = 1.56$], Male = 8, Female = 33; N = 41 for EPT, ages ranging from 18 to 24 [$M = 20.12$, $SD = 1.75$], Male = 6, Female = 35) undergraduate students. The University of Waterloo Research Ethics Board approved all study procedures. Written informed consent was obtained from all participants. Research was completed in accordance with Helsinki Declaration.

3.2. Materials

Forty-five single-action verbs were selected (e.g. throw, chop) from the Max Planck Institute for Psycholinguistics WebCelex (see Appendix). Action verbs ranged in frequency from 1 to 464 ($M = 70.04$, $SD = 99.69$) based on the Frequency Analysis of English Usage (Francis et al., 1985), varied in length from 3 to 7 letters ($M = 4.60$, $SD = .96$), and had either one or two syllables ($M = 1.13$, $SD = .34$).

3.3. Procedure for SPT group

The experiment was conducted via Microsoft Teams (version 1.4.00.26376). A fixation-cross was presented (500 msecs), followed by a prompt

[2]This sample calculation was based on the study by Mulligan and Hornstein (2003).

(presented for 1 sec; font size: 16, colour: black, font style: Courier New) specifying participants to "enact" (participants performed a related action), perform a "non-representative gesture" (write verbal targets in air), or "read" target words. Forty-five action verbs (target word was presented for 4.5 secs) intermixed by encoding type (enact, non-representational gesture, or read) were presented and participants were verbally instructed to repeatedly perform the action or read the words on the screen for a duration of 4.5 s. Each item from the stimulus list was presented only once to the participant. The order of trial type was counterbalanced across participants following a Latin Square Design (Preece & Freeman, 1983). Each participant was tested individually and viewed their own independent randomisation of words and encoding trial types. After the encoding phase, participants were instructed to count backwards from 190, by 3s out loud, for 20 secs to prevent recency effects. Participants were then given 60 secs to recall as many words as they could, from the study phase, by typing each word into the chat box within Microsoft Teams. Following recall, a Qualtrics web link to complete Set A of the MHVS was sent to the participant via the chat box within Microsoft Teams. The entire session lasted approximately 10 min in total.

3.3.1. Procedure for EPT group

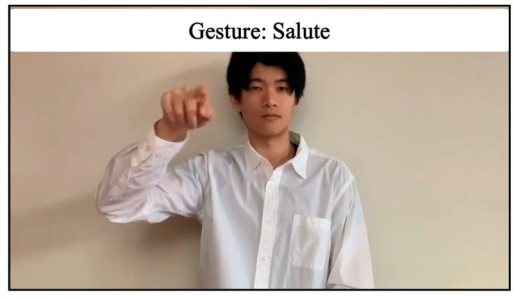
Stimulus presentation and response recording was also conducted on Microsoft Teams (version 1.4.00.26376) using the screen sharing function, whereby participants viewed actions performed by the researcher via 4.5-sec videos. A fixation cross appeared first on the screen for 500 milliseconds, followed by videos (4.5 secs) of each of the 45 target words (videos were created using Filmora; version 9.6.1.8; Wondershare, 2020), in which a research assistant was shown enacting (performing a related action), gesturing (writing the word in the air), or reading target items twice for each corresponding item on the screen. Participants simply observed the videos; actions were not performed during encoding. The word and the label of trial type was specified to be 36-pt Times New Roman font on the top of the video (see Figure 1(a–c)). The presentation of all 45 videos took 225 s. The order of trial type was counterbalanced across participants following a Latin Square Design (Preece & Freeman, 1983), as in the SPT procedure. After the encoding phase, participants were instructed to count backwards from 190, by 3s out loud, for 20 secs to prevent recency effects. They were then instructed to type the recalled words into the Chat box in Teams and send them to the researcher (recall phases was 60 secs). After recall, a Qualtrics link containing Set A of the Mill Hill Vocabulary Scale (MHVS) was sent to the participant via the Chat box. The entire session lasted approximately 15 min in total.

3.4. Results: main effect of encoding strategy on recall

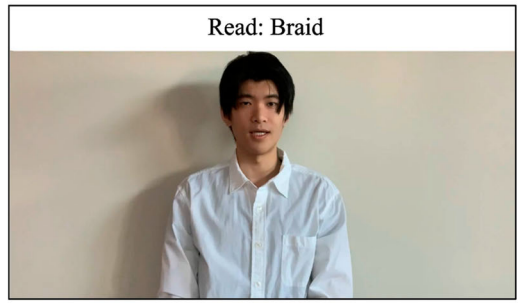
We conducted a 2 X 3 mixed ANOVA, with Encoding Strategy as the within-subject variable consisting of three levels (enact, non-representational gesture,



Panel a. Enact trial



Panel b. Non-representational gesture trial



Panel c. Read trial

Figure 1. Experimenter-produced task trial types. Panel a. Enact trial; Panel b. Non-representational gesture trial; Panel c. Read trial.

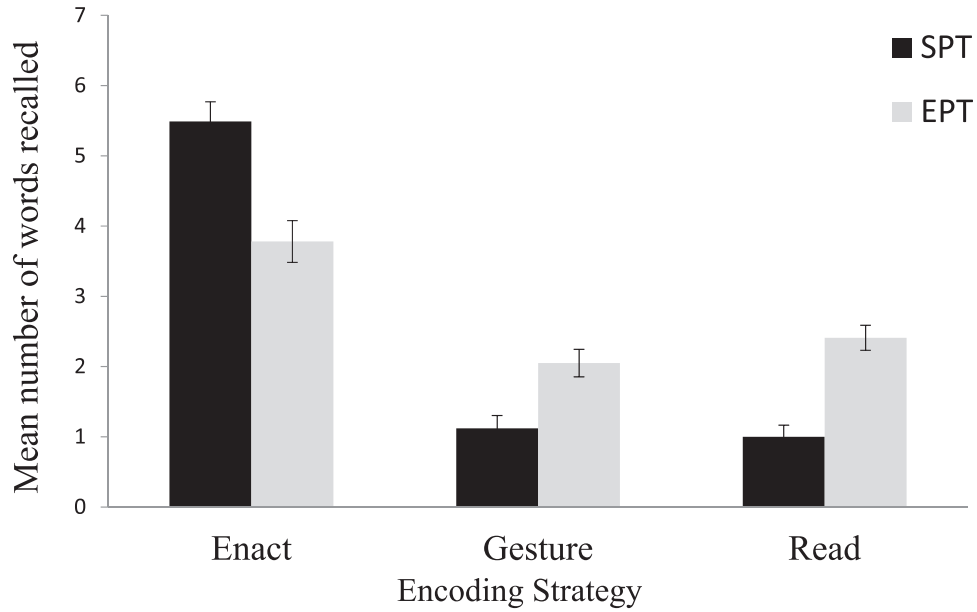


Figure 2. Mean number of words recalled for each encoding trial type (Enact, Gesture, Read) in the Subject-performed task (SPT) and Experimenter-performed task (EPT) groups. Error bars represent the standard error of the means.

and read), and the between-subject variable as Group consisting of two levels (Subject-performed task or Experimenter-performed task), on number of words recalled.[3] We observed a significant main effect of encoding strategy on Group, $F(1.73, 138.02)^{4} = 122.77$, $MSE = 2.31$, $p < .001$, $\eta^2_p = .61$, such that words enacted (semantically related actions) at encoding were better remembered than those encoded with non-representational gestures, or by reading (see Figure 2 for means)..[5]

There was no significant main effect of Group (SPT vs. EPT), $F(1, 80) = 1.52$, $MSE = 1.81$, $p = .222$, $\eta^2_p = .02$, on memory performance, though there was a significant Encoding Strategy X Group interaction, $F(1.73, 138.02) = 29.06$, $MSE = 2.31$, $p < .001$, $\eta^2_p = .27$. To understand the interaction, we conducted separate one-way ANOVAs for each Group. For the SPT Group[6], we observed a significant effect of encoding strategy on recall performance, $F(1.49, 59.51) = 163.17$, $MSE = 2.21$, $p < .001$, $\eta^2_p = .80$. For the EPT Group, we also observed a significant effect of encoding strategy, though the effect size was smaller, $F(2, 80) = 14.61$, $MSE = 2.34$, $p < .001$, $\eta^2_p = .27$. Number of words recalled was significantly higher following enactment in the SPT Group, than in the EPT Group (SPT: $M = 5.49$, $SD = 1.80$; EPT: $M = 3.78$, $SD = 1.71$), $t(80) = 4.40$, $SE = 0.39$, $p < .001$. SPT provided a 59.51% boost to memory, whereas EPT provided a 18.41% increase in recall relative to the read trial type. Following non-representational gestures, memory was significantly higher in the EPT compared to SPT Group (SPT: $M = 1.12$, $SD = 0.95$; EPT: $M = 2.05$, $SD = 1.43$), $t(80) = -3.45$, $SE = 0.27$, $p < .001$. Following the read condition, memory was also higher in the EPT than in the SPT Group, $t(80) = -5.79$, $SE = 0.24$, $p < .001$ (SPT: $M = 1.00$, $SD = 0.74$; EPT: $M = 2.41$, $SD = 1.38$).

3.4.1. Results: onset time to initiate encoding task in the SPT group

For each participant in the SPT group, we calculated the onset time to initiate the prompted encoding task to the target word for all forty-five words (15 words enacted, 15 words gestured, 15 words read). We accomplished this by computing the difference between the onset time of presentation of the target on the screen, and when the

[3]These results were the same when Proportion recalled was used as the dependent variable.
[4]Mauchly's test indicated that the assumption of sphericity had been violated, $\chi 2(2) = 13.70$, $p = .001$, thus, a Greenhouse-Geisser correction was applied.
[5]To calculate recall score we counted how many words participants correctly recalled from the target word list, separately for each encoding strategy.
[6]Mauchly's test indicated that the assumption of sphericity had been violated, $\chi 2(2) = 16.47$, $p = <.001$, thus, a Greenhouse-Geisser correction was applied.

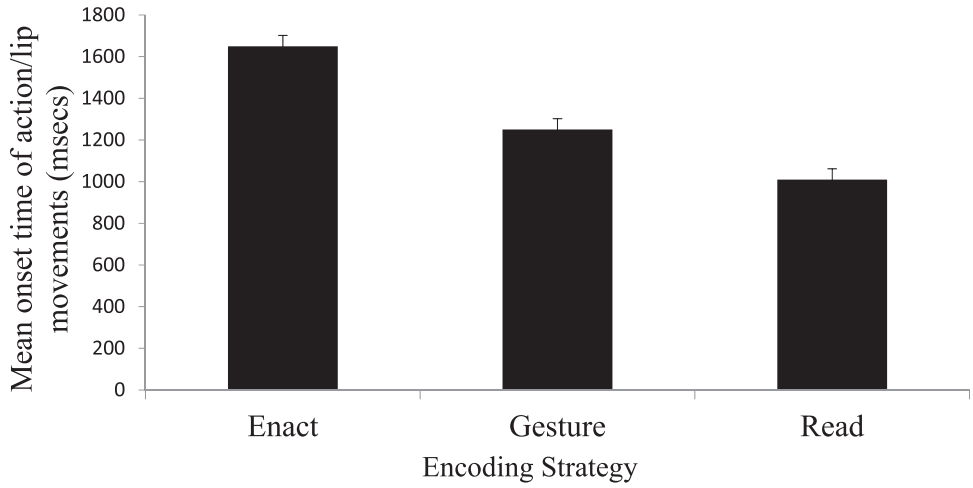


Figure 3. Mean onset time of action on Enact and Gesture trial types, and lip movements during Read trials in the Subject-performance task group. Error bars represent standard error of the means.

participant responded by initiating an action (enact or gesture) or moved their lips to read. Action onset was obtained by downloading an extension named Time (version 3.2) to VideoLan Client (VLC) media player (https://addons.videolan.org/p/1154032). It enabled us to retrieve the precise timing for when the stimulus (target word) was presented and record the onset time of a participant's initiation of action to target words (enact, non-representational gesture, read). The timings were obtained manually by a research assistant who scrolled through each of the videos, and was naïve as to the experiment's hypotheses. For example, if the target was presented at 4 mins, 53 secs, and 605 msecs (shown by the software as 04:53, 605), and the action was initiated at 4 mins, 55 secs, and 853 msecs, we calculated the time difference as a proxy of the time taken to plan and execute that action (2 secs and 248 msecs).

We examined these data using a one-way repeated measures ANOVA (see Figure 3 for means). Mauchly's test indicated that the assumption of sphericity had been violated, $\chi 2(2) = 7.38$, $p = .025$, thus a Greenhouse-Geisser correction was applied. There was a significant main effect of Encoding Strategy on Onset Time, $F(1.71, 68.24) = 75.88$, $MSE = 0.07$, $p < .001$, $\eta^2_p = .66$. Bonferroni-corrected paired sample t-tests revealed that the onset time for initiating non-representational motoric gestures to target words was significantly faster relative to enacting them, $t(40) = 9.88$, $SE = 0.04$, $p < .001$. Lip movements during the reading trials were also initiated significantly faster compared to initiating hand movements on enactment, $t(40) = 11.22$, $SE = 0.06$, $p < .001$, and on non-representational gesture trials, $t(40) = 4.18$, $SE = 0.06$, $p < .001$.

4. Discussion

Past studies have shown that physically performing an action depicting a word, during its encoding, enhances memorability for the word relative to simply reading it. In our study, we examined whether the performed action needed to be semantically related to the word to enhance memory. Prior studies have also shown that observing an experimenter perform an action can aid memory to a similar degree. We asked whether this EPT effect would be maintained even when the experimenter was not physically present, but seen in a video. We report three main findings in this study. First, performing or observing semantically related actions, but not gesturing, enhanced memory significantly relative to reading. Second, in the SPT group, we measured the onset time of action initiation for the motoric tasks as an index of cognitive planning, and found that participants took measurably longer to initiate an action on enactment relative to non-representational gesture trials. Third, the magnitude of benefit from performing related actions at encoding was significantly greater when participants performed (SPT) rather than when observing (EPT) these actions. We discuss each finding in turn.

Our results show that simply engaging in any overt motoric activity during encoding does not enhance later memory for target words. The motor activity needs to illustrate the target in order to be

effective. Further, it is plausible that participants would have perceived a "word in the air" mirrored during the non-representational gesture trials in the EPT condition compared to the SPT condition. However, we do not believe this would have affected the results as the primary purpose of the gesture trial type for the EPT condition was for participants to observe an action that did not depict the meaning of the visually presented target word. Even observing a mirrored "word in the air" would produce an action that is conceptually unrelated to the target item.

In addition, we asked participants to type their responses during later recall, since this study was conducted remotely, and we wanted to retain text files of all participant data without having to manually note down responses from the video-recorded files. Although this method may be contrary to what has been done in previous studies, this method of typed recall did not significantly influence the predicted enactment benefit (in SPT relative to read). It could be argued that the act of typing recall could have reduced output. However, the requirement to type recall was consistent across the SPT and EPT conditions, thus any detriment to memory elicited by typed recall would have similarly reduced performance in the SPT condition (but it did not). Further, some could argue that the unrelated actions performed during the non-representational gesture trials might serve to be disruptive or distracting motor activity during encoding, subsequently affecting the recall performance of participants. We note that the order of the three intermixed encoding trial types in our experiment was randomised during the presentation. Therefore, any cognitive load or motoric disruption/interference evoked by the non-representational gesture condition would have equivalently affected delayed recall for all three trial types. However, this was not the case. We instead suggest that when a semantically related action is performed at encoding (as is the case for enacted words), both motor and verbal representations are retained. Performing a non-representational gesture, however, fails to establish a supplementary motor trace to aid memory. Our suggestion explains why recall for both gesture and read conditions are significantly lower relative to enactment, as participants only had the verbal coding to aid recall. Importantly, this finding replicates our recent study in which we investigated whether the action created during encoding needed to be semantically relevant to the to-be-remembered word, to enhance memory (Sivashankar & Fernandes, 2022). In that study, and here, we suggest that planning and executing any distinctive movement at encoding is not sufficient to produce an enactment effect; integration with semantics drives the benefit. Further, we found superior performance in the EPT Group following non-representational gesture and reading relative to SPT. Participants performed an irrelevant action during the non-representational gesture trials for EPT as opposed to performing one on their own. We speculate that the negative effect of performing an irrelevant action was attenuated in the EPT group since participants were simply observing the actions. For the read trial, a slight benefit may have been conferred when participants could see someone else's lip movements reading the word.

In addition, we found that enactment conferred a memory benefit to free recall even though initiating a related hand movement took, on average, longer compared to initiating a non-representational gesture. This suggests that planning of any unique action such as one that simply represents the orthographic structure of word forms, is not sufficient to generate the enactment effect (Ratner & Foley, 1994; Zimmer & Engelkamp, 1996). Simply put, the action must be conceptually related to the meaning of target items. This claim is supported by our finding of poorer recall for words gestured at encoding relative to words enacted. In our experiment, the movement onset time during SPT, on read trials was significantly faster relative to enact and non-representational gesture trial types. Similar to executing non-representational gestures, in the read condition participants did not need to engage in elaborative processing of the target in order to read the word. The limited action planning of the verbal target may explain the poorer memory performance for words read, relative to words enacted at encoding. That enactment conferred a memory benefit, despite the longer onset time of action initiation, is in line with claims that task-related action planning may serve as another mechanism underlying the enactment benefit (Ratner & Foley, 1994, 2020; Zimmer & Engelkamp, 1996). That is, the memory advantage may depend on a cognitive system that must retain motoric representations of planned action sequences (Jaroslawska et al., 2018). We believe the action onset measures reported here represent a critical novel addition to our understanding of why enactment benefits

memory. That is, the longer onset time of action initiation for enacted words suggests that planning of an appropriate action (selection and evaluation of an adequate action, followed by recruitment of the relevant motor programme) may be a critical component influencing memory performance.

We also found that performing an action during encoding that depicted a to-be-remembered word, significantly improved its memorability relative to observing an experimenter perform meaningful actions to target words. These findings highlight the very mechanisms by which enactment and action observation are predicted to benefit memory. Enactment is predicted to benefit memory for distinct items, supporting performance on recognition tests of memory, while action observation is thought to enhance memory for relational processing among items in a word list, supporting free recall of words (Engelkamp & Zimmer, 1984, 1985; Zimmer et al., 2001). In our experiment, we employed a recall test when assessing the relative benefit of SPT and EPT to memory performance, which therefore should have benefited performance in our EPT group. Our experimental design was also blocked. Research shows that memory is typically better for SPT items when lists are intermixed, rather than blocked, across EPT and SPT (Engelkamp & Krumnacker, 1980; Engelkamp & Zimmer, 1997). This is believed to occur because block designs reduce any differential benefit of SPT due to distinctive encoding of verbal targets (Zimmer et al., 2001). Given these aspects of our design, we ought to have observed comparable memory from SPT and EPT conditions: our assessment of memory was a free recall test, which favours EPT items and we employed a block design, which limits distinctive processing of SPT items. In contrast, we found free recall was significantly higher in our SPT relative to EPT condition.

We speculate that watching a video of another person enacting, without a social/physical presence as in our study, may have limited attention to the experimenter's actions, or could have limited the engagement of the mirror-neurone system (Shih et al., 2017) hypothesised to mediate EPT effects (Ianì & Bucciarelli, 2017; Ianì et al., 2018). It is important to note, however, that some researchers (Hickok, 2009) have refuted the existence of mirror neurones in supporting understanding of actions in humans. For example, research studies have been able to dissociate regions associated with the human "mirror system" from action understanding (Buccino et al., 2004; Catmur et al., 2007). Thus, it is plausible that action understanding may stem from the functioning of other brain areas such as the frontal motor cortices that play a critical role in action execution (Fadiga et al., 1995). It should be noted, however, that we did not experimentally investigate whether patterns of memory benefit would differ when EPTs were observed in person versus online. Nonetheless, our results highlight, for the first time, that physical presence may be an important factor to consider in future research investigating memory benefits gained following observation of EPT.

In line with our finding, recent research investigating the impact of lectures delivered through online educational videos suggest that the level of physical presence evoked by remote learning (measured by facial expression of the instructor, eye contact, posture, proximity) is indeed critical to student's understanding and retention of material (Kim et al., 2016; Woods & Baker, 2004). Further, many students report that sustaining attention to lecture content is more difficult, and rates of student engagement decline more rapidly, when lectures are online as opposed to in-person (Glassmeyer et al., 2011; Kim et al., 2014; Lunn et al., 2020). Pan and colleagues (2020) suggest that the physical absence of an instructor who might be able to improve students' focus on the video content may be one reason why maintaining attention to online content may be difficult.

5. Conclusion

Overall, our results show that semantic relatedness of the action to the target is critical to observe a memory benefit. Specifically, this study supports the use of semantically related actions, but not meaningless or non-representational gestures, to enhance memory of target information. Our results also indicate that the magnitude of benefit is greater for SPT than EPT, when the latter is viewed in a video.

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Data availability statement

The data sets (First link: Main effect of encoding strategy on recall; Second link: Onset time to initiate encoding task in the SPT group) that support the findings of this study are openly available in Open Science Framework at [https://mfr.osf.io/render?url=https%3A%2F%2Fosf.io%2F34fuq%2Fdownload] and [https://mfr.osf.io/render?url=https%3A%2F%2Fosf.io%2Fkjghr%2Fdownload].

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Appendix

List of target items

Drive	Salute	Braid
Throw	Dig	Dribble
Type	Swim	Dive
Chop	Flick	Climb
Whisk	Juggle	Count
Applaud	Tap	Sweep
Comb	Wave	Row
Knock	Flex	Serve
Punch	Catch	Stroke
Knit	Tear	Honk
Stir	Paint	Stop
Greet	Drink	Wipe
Pour	Cut	Carry
Crawl	Hug	Snap
Eat	Hammer	Bend

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