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False Memories of Actions: When Motor Simulation is Deceptive

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Abstract

Seeing a person preparing to perform an action and later remembering having seen subsequent phases of the action, but not previous phases. This is what a theory on the role of the motor system in the creation and recovery of memories predicts can happen. We investigate memory for action after viewing an image representing an actor acting on a series of everyday objects. The participants in one experiment viewed a series of still photos of unfolding actions on objects (e.g., blowing the nose), and 15 minutes later they were asked to complete a recognition task. At recognition, participants viewed photos representing temporally distant moments, backward or forward in time compared to the original, along with the same photos seen at encoding. Results showed that participants tended to accept forward photos more than backward photos. In a pilot study, we explored the role of the temporal distance between encoding and recognition. Results showed that when 3 days elapsed between the encoding and recognition phases, participants did not tend to accept forward photos more than backward photos.

Keywords: false memories; action; kinematic mental simulation; motor system

Introduction

Viewing a still image of an action triggers a motor simulation of the action unfolding over time (e.g. Urgesi et al., 2010). This cognitive process is essential for effective interaction with the environment, but can also lead to perceptual and memory errors, such as distorted representations of a moving target shifted in the direction of implied motion (Hubbard, 2005), or the construction of distorted memories of the observed action (Ianì et al., 2020). This potentially detrimental effect was first demonstrated in studies on representational momentum (e.g. Freyd & Finke, 1984). In representational momentum paradigms, participants typically first look at a photo showing an actor or object in motion. Then the photo disappears and a new photo appears on the screen. In this perceptual task, they judge whether it is exactly "the same" or "different from" the first one. The results of one study show that it is more difficult for participants to reject distractors when they are photos of the same scene taken at a later time than when they are photos taken at an earlier time (e.g. Freyd, 1983). This phenomenon, known as the "forward effect", is thought to be due to the mental representation of the action shifting along the pattern of motion implied in the photo (for a review, see Hubbard, 1995; 2005).

Earlier studies in the literature have shown that false memories can also arise from watching movies or still images of action sequences. Gerrie, Belcher and Garry (2006) found that when participants in their experiment watched a movie about a woman preparing a sandwich and some actions were missing from the movie, they falsely remembered 17% of unseen elements from the event in a subsequent memory test. It happens that seeing individual images of action sequences that represent an effect but not a cause can lead to new cause scenes being confused with old ones in a recognition test, i.e. automatic inferences are drawn (Hannigan & Reinitz, 2001). Foster and Garry (2012) argue that these findings about the effects of watching movies or action sequences can be explained by the assumption that people use the relationship between elements to generate the missing related information internally. However, memory errors concerning future rather than past states of affairs have not been much investigated, nor have the mental representations and processes that underlie the formation of false memory of actions.

Ianì, Mazzoni and Bucciarelli (2018) assume that the observation of actions triggers a kinematic mental model that unfolds in time and the sequence of situations it represents corresponds to the temporal sequence of events in the real or imaginary world (Johnson-Laird, 1983; Schaeken, Johnson-Laird, & d'Ydewalle, 1996). This assumption leads to the prediction that false memories can arise from such kinematic mental models. Ianì et al. (2018)

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have found evidence for the existence of such spontaneous false memories in which meaning-connectedness knowledge plays no role, as they stem from the activation of the motor system. In one experiment, participants first saw photos in which actors were about to perform actions on objects. At recognition (three days later), they randomly encountered, along with each original photo (hereafter "original"), a photo showing the conclusion of the action seen in the original photo (hereafter "forward") and two other photos showing a different action by the same actor on the same object: one photo showed this action two-thirds of the way through completion and the other one depicted its completion (hereafter "other1" and "other2", respectively). Consequently, "forward" represented a situation that should be part of the kinematic mental simulation of the "original", while the situation represented in "other2" should also be part of a mental simulation, but this time it should be the mental simulation created on the basis of the action represented in "other1". The participants' task was to rate their confidence that the photos had been presented during encoding on a five-point scale from 1 ("I certainly didn't see this photo") to 5 ("I certainly did see this photo"). Participants assigned an average confidence of 3.96 to the "original" photos and 2.47 to the "forward" photos. The latter was significantly higher than the average confidence assigned to the "other2" photos, which show the completion of another action on the same object (M = 1.85). Thus, when participants saw a photo of an actor holding a bottle to drink from during encoding, they were more confident that they had already seen the photo of the actor drinking than a photo showing the final state of another action on the same object (e.g., pouring water from the bottle). These results show that by viewing photos, participants developed a structured internal model of the system to be predicted, a model that is "isomorphic on a part by part basis to that external system, and contains information about the mechanics of its movement properties"' (Wilson & Knoblich, 2005, p. 466). In this way, the perceptual system generates predictions by running "online" simulations (Wilson, 2002): as the external event unfolds, the simulated event likewise unfolds in the same way and at the same pace. The duration of such effects is crucial, because several theoretical approaches interpret these so-called "kinematic false memories" as the result of a bottom-up process that is triggered exclusively by the perception of an action at a particular moment. The observation of actions should lead to a "motor inference" (Ianì et al., 2020) quickly and almost automatically (Wilson, 2001), in relation to what is going to happen. According to this view, such motor inference (sometimes referred to as "motor resonance", Ianì, 2021) allows the observer to immediately anticipate the behaviors of others and effectively interact with the immediate surroundings (e.g., Flanagan & Johansson, 2003). This mechanism thus seems to be primarily linked to the moment in which the action is perceived.

The present study aims to understand more deeply the false memories stemming from kinematic simulations in action observation, i.e., mental simulations that rely heavily on the activation of the observer's motor system (e.g., Gallese, 2007). The novelty of the study is the investigation of the extent to which people are susceptible to generating spontaneous false memories of the natural continuation of an action compared to its previous phases. The creation of false memories of a photo representing a later phase of a seen action could be the result of mental simulation during action observation.

Previous studies in the field of action perception (Ianì et al., 2021; Ianì et al., 2023) have shown that when participants saw a photo representing actions unfolding in time, they were faster in the evaluation of photos showing the forward phases of the actions compared to photos showing the backward phases, both in explicit and implicit tasks. These results suggest a mandatory mechanism by which our brain simulates action even in tasks that do not explicitly require action simulation. The mandatory forward simulation during action observation could lead to the integration of the forward phases into the memory of a seen action, as opposed to the backward phases.

To investigate whether participants are more likely to spontaneously develop false memories for the later phases of a seen action than for the earlier phases, we conducted an experiment in which participants were asked to recognize the photos seen at encoding 15 minutes after encoding and a pilot study in which they were asked to recognize the photos three days after encoding. In the recognition phase, the participants were presented with the 10 original photos they had seen at encoding. For 5 of them, they were presented with 5 photos that represented the earlier stages of the actions, and for the other 5, they were presented with 5 photos that represented the later stages of the actions.

The Bioethical Committee of Turin University approved the investigation.

Experiment

Participants observed a series of photos, each depicting the central part of an action (e.g. blowing the nose) and then performed a 15-minute distraction task. Then they performed a recognition test in which they encountered the photo presented at encoding along with either a photo depicting something that happened before the event depicted in the photo seen at encoding (i.e., a Backward photo) or a photo depicting something that happened after what was depicted in the photo seen at encoding (i.e., a Forward photo). The task was to decide whether the action in the photo represented something that was seen at encoding or something that was not seen at the encoding.

Participants should accept more forward photos as seen at encoding compared to backward photos. In other words, participants should be more prone to form false memories for something that happened after what they saw than for something that happened before.

Method

Participants

Using an a priori power analysis, we estimated that at least 53 participants were required to obtain a suitable statistical power level of .90 to detect a significant paired comparison (with $\alpha = .05$) and, assuming a medium effect size (dz) of 0.46 as detected in previous studies (e.g. Ianì et al., 2021).

Seventy-one participants (26 males and 45 females, mean age = 23.55, *SD = 4.02*) voluntarily took part in the experiment in exchange for a course credit. They previously signed the informed consent.

Materials

The material consisted of 10 videos from a previous study (Ianì et al., 2021). Each video shows a single action performed by an actress with the upper limbs, either with one or two arms (e.g., eating a hamburger, drinking water from a glass). Each video was cut into three same-length parts; the middle frame of the second part was presented to the participants at encoding (stimulus photo). Two additional photos were extracted for each action video: the central frame of the first part (Backward photo) and the central frame of the third part (Forward photo). These photos were presented to the participants at test together with the photos presented at encoding. Figure 1 shows examples of the stimuli for the "Blow the nose" video.

Figure 1: The images extracted from the video "Blow the nose" and presented to participants at encoding (Stimulus) and at test (Backward, Forward, Stimulus).

Design and Procedure

We used a within-subjects design with Types of photos (Backward, Forward) as within-subjects factors. At the recognition, each stimulus was combined with either a backward or a forward photo. Thus, we developed two protocols: in Protocol 1, participants saw the 10 stimulus photos, 5 of which were accompanied by a Backward photo and the other 5 by a Forward photo. In Protocol 2, we reversed the associations for the scenarios that were initially linked to Backward and Forward photos in Protocol 1. For each participant, the stimuli were presented in a random order.

The experiment took place online. Participants received an email with instructions to download E-prime Go (Psychology Software Tools, 2020), an extension of the software used to conduct online experiments. At encoding, participants received the following instructions via a computer screen:

> Thank you for participating in this experiment on how we understand the unfolding of an action over time. In this phase you will see a series of photos. Each photo represents an actress performing an action. Your task is to carefully observe each photograph.

Soon after the encoding participants performed a 15-minute distractor task in which they were asked to find twenty differences between a series of two vignettes. The vignettes did not depict people or actions. After the distraction task, participants performed the recognition test. They received the following instructions via a computer screen:

> In this second phase, you will see a series of photos showing an actress performing various actions. Your task is to decide whether you have already seen the photo in the first phase of this experiment. Press the 'V' key if you think you did see the photo in the first phase and press the 'N' key if you believe you did not see it. Please keep your fingers on the 'V' and 'N' keys to respond as soon as you are sure of your answer. When you are ready to begin, press the spacebar.

When the participants were ready to start, they pressed the spacebar and the first photo appeared on the screen. When they pressed the 'V' or N' keys, a white screen with the text "Next photo" appeared on the computer screen for 3 seconds, followed by a 250 ms fixation cross. A new photo then appeared on the screen. In total, each participant saw 20 photos (10 stimulus photos, 5 backward photos and 5 forward photos) presented in random order. We coded the accuracy of participants' responses and, for exploratory purposes only, response times. To ensure correct measurement of response times, participants were instructed to keep their fingers on the 'V' and 'N' keys and to press one of them as soon as they were sure of their response

Results

We analyzed the data from the 71 participants to examine whether participants differed in their ability to discriminate backward and forward phases of an unfolding action they had previously seen. To this end, we applied signal detection theory to our data to assess how participants discriminated between signal and noise trials. Participants were presented with 10 signal trials and 10 noise trials (i.e., five backward photos and five forward photos), and we computed d' for both backward and forward photos, a measure of signal detection sensitivity (z-scored hit rate minus z-scored false alarm rate; Green & Swets, 1966). In signal trials, 'V' responses were correct (hits); in noise trials, 'V' responses were incorrect (false alarms). Because the signals differed markedly from the noise trails, some hit and false rates were equal to 1 (corresponding to a z score of $+\infty$) or 0 (corresponding to a z score of $-\infty$). Therefore, the hit and false alarm rates were calculated by adding 0.5 to both the number of hits and the number of false alarms and 1 to the number of signal and noise trials (Hautus, 1995).

We performed a paired-sample t-test between the d' for backward photos and the d' for forward photos, which revealed a significant difference ($t(70) = 2.48$, $p = .016$, Cohen's $d_z = .29$). Thus, in line with our prediction, participants were more prone to accept forward photos (mean *d'* = 1.57, *SD = .74)* as seen than backward photos (mean *d'* = 1.86, *SD* = *.66*). Figure 2 shows the mean value of the d' and the relative standard deviations for both the backward and forward photos.

Regarding response times, we performed a paired-sample t-test between the mean of response times for correct recognition of backward photos (mean = 1963.41; *SD = 1202.96*) and the mean of response times for correct recognition of forward photos (mean = 1968.38; *SD* = *1326.11*). The results showed no significant difference between the response times for backward and forward photos (t(70) = -.03, *p* = .97, Cohen's d_z = .00). Thus, participants needed the same amount of time to correctly recognize backward and forward photos.

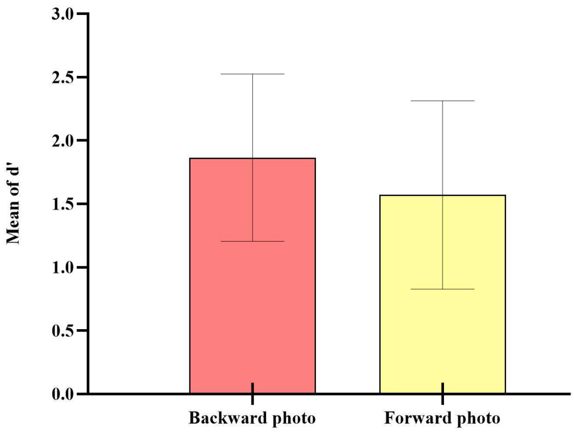

Figure 2: The mean value and the standard deviations of d' depending on the type of photo (Backward, Forward).

Pilot study

In order to investigate whether the effect observed in the experiment persists over time, we developed a pilot study in which the material and the participants' task were the same as in the experiment, but there was a three-day interval between the encoding phase and the recognition phase. For this reason, no distracting task was performed after encoding. The results presented in this study should be considered preliminary, as ongoing data collection is part of our commitment to comprehensively explore and analyze the research variables by manipulating time between the encoding and recognition phases in a study with a between-subject design.

Method

Participants

30 participants (11 males and 19 females; M = 24.66 years, *SD = 2.62*) voluntarily took part in the present experiment in exchange for a course credit. They previously signed the informed consent.

Materials and Procedure

The materials and the procedure were the same as in the experiment, except that the participants performed the recognition task three days after the encoding rather than 15 minutes after the encoding.

Results

The data from 2 participants were removed from the analysis because the audio recordings of the participants' responses were disturbed. The following analyses are therefore based on the remaining 28 participants.

As in the experiment, we computed the d' for backward (mean *d'* = .72, *SD = .21*) and forward photos (mean *d'* = .70, *SD = .23*) and performed a paired sample t-test between these two indices. The results showed no significant difference between participants' ability to discriminate backward and forward photos (t(27) = -0.116, *p* = .91, Cohen's d_z = .01).

We also report Bayes factors to determine the relative probability of observing the present data under the null hypothesis compared to the alternative hypothesis (see Rouder et al., 2009). Bayes factor tests were run using the JASP software (JASP Team, 2017) with a default JASP prior, i.e., a Cauchy prior with a location parameter of 0 and a scale parameter of 0.707. Evidence in favour of the null hypothesis is denoted BF_{01}. For the comparisons between d' in backward and forward conditions, we obtained a BF_{01} of 4.96, which is a strong indication of the absence of a significant difference.

In contrast to the experiment, in which participants were more likely to believe they had seen a photo representing a later phase of an observed action than a photo representing an earlier phase of the same action, the participants in this pilot study did not show this tendency. The absence of this effect could be due to the longer time interval between the encoding and recognition phases. It is important to point out that additional data are needed to provide a more precise answer to the question of the absence of this effect.

As in the experiment, we analyzed participants' response times only for the correct recognitions. We performed a paired-sample t-test between the mean of response times for correct recognition of backward photos (mean = 1759.80, *SD = 784.7*) and the mean of response times for correct recognition of forward photos (mean = 1755.25, *SD = 507.4*). The results showed a non-significant difference between the response times for correctly recognizing backward and forward photos (t(26) = .38, *p = .97,* Cohen's d_z = .00). In line with the results of the experiment, the participants therefore needed the same amount of time to correctly recognize backward and forward photos.

Discussion

The assumption underlying the present investigation is that viewing a photo showing a static scene of an actor near to perform an action triggers a kinematic mental simulation of that action unfolding in time. The prediction is that the kinematic mental model will more strongly support the creation of a false memory for the actor performing an advanced phase of the action (a forward false memory) than for the actor performing an earlier phase of the action (a backward false memory). The results of the experiment confirm the existence of false forward memories to the detriment of false backward memories. The results of the pilot study, in which the participants performed the recognition three days after the encoding, do not confirm the results of the experiment. It is possible that the actions shown were too elementary to detect the presence of false forward memories versus false backward memories over time. From simple observation of the stimuli (see the Backward, Stimulus, and Forward frames in Figure 1), it is clear that the stimulus triples are easily confused after three days. However, such results are to be interpreted with extreme caution, as we need to manipulate time between the encoding and recognition phases in a study with a between-subject design.

Overall, our results suggest that the mental kinematic simulations can lead to false memories. While the construction of a mental kinematic simulation has been found so far to be associated with correct performances (e.g. Bucciarelli et al., 2016), this is a demonstration that it can also lead to mistakes.

Future studies could use more complex actions. Namely, we can hypothesize that seeing a person unwrapping a piece of candy during encoding and seeing the image of the same person taking the candy (Backward) and throwing away the candy wrapper (Forward) in addition to the same image during recognition can lead to later misremembering that one saw the person throwing away the candy wrapper.

Future studies could also investigate the potentially different mechanisms underlying false forward and backward memories. Because individuals typically perform kinematic mental simulations in the forward direction, we hypothesize that backward false memories of the causes of an action rely on different processes than forward false memories of the effects of an action. In this regard, the mechanism underlying backward false memories should not be a kinematic mental model, but rather the induction of an explanation, an abductive reasoning process that relies heavily on prior knowledge.

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