EFFECTS OF MOTOR INVOLVEMENT ON MEMORY PERFORMANCE FOR PICTORIAL AND 3D OBJECTS

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Abstract

Recent research indicates that memory for real objects is superior to memory for matched pictures (Snow, Skiba, Coleman, & Berryhill, 2014). Although there are several possible explanations for this memory difference, this study was specifically interested in assessing the role of motor involvement. Since real objects offer affordances for action, they may unconsciously engage the motor system when they are viewed. If the motor involvement explanation is correct, I hypothesized that fully engaging the motor system by having individuals interact with the objects should further enhance memory for objects but not for pictures. The study used a 2 (stimuli: object vs picture) x 2 (task: motor vs non-motor) between-subjects design. Thirty participants were randomly assigned to each of the four conditions. Participants engaged in a simple judgment task which involved making a decision by grasping the stimuli (motor) or writing the decision on paper (non-motor). Following the task, recall and recognition scores were assessed. As hypothesized, recall for objects was further enhanced in the motor condition relative to the non-motor condition, and no such improvements were found across the picture conditions. The results of this study suggest that motor system involvement facilitates enhanced memory for objects.

Effects of Motor Involvement on Memory Performance for Pictorial and 3D Objects

Memory is an essential function that provides the foundation for all cognitive processes. Without memories from the past, future experiences would lack meaning. There are various forms of information stored in human memory. These different types of information are accessed and retrieved to act as a guide for human behaviour. When looking at the different forms of information, it is the unspoken assumption that memories for pictures will be remembered better than our memories for studied words. The well-known phrase “a picture is worth more than a thousand words” suggests that our memories for visual displays are something far from ordinary. When people look at pictures, they observe them as a means to understand the story being conveyed. Children for instance, follow stories by observing pictures in books before they have formed a concrete understanding of language. In a sense, words are limited by knowledge, but pictures are easier to understand because they share a universal meaning. For example, despite language barriers, a person travelling in any airport will be able to locate the appropriate washroom by looking at the image on a sign.

Pictures are better than memories for words; however, this is not necessarily true when compared with objects (Snow, Skiba, Coleman, & Berryhill, 2014). A picture can be worth a thousand words but becomes useless if a person cannot remember what happened. In a study conducted by Henkel (2013), participants were taken to an art museum and instructed to observe certain objects for several minutes and quickly photograph others. The results of this study demonstrated a memory advantage for objects. Participants remembered fewer details for photographed objects, whereas they were able to report more details for objects that were observed. Overall, the findings of this study lent support in suggesting that our memory for objects is more superior than our memory for pictures

In the field of memory research, an extensive body of empirical information exists detailing memory for images or words but less exists regarding memory for real objects. Objects are perceptually richer than pictures, and this visual distinction may lend support in suggesting that they are more memorable. Our behaviours are structured around objects more than they are around words or pictures. Imagine baking a cake. When you are baking a cake, you may not follow the instructions of a recipe sequentially step by step; rather, your performance is facilitated by knowing where objects are found within your kitchen. This is because a lot of our memory performance is influenced by objects (Snow et al., 2014), and one may assume that objects are stored and processed in memory differently than words and pictures (Snow et al., 2014).

Snow, Skiba, Coleman, and Berryhill (2014) were the first to compare memory for real objects with pictures. Prior to their study, they assumed that memory for real objects was equivalent to memory for images. Their motivation was to explore the possibility of whether memory for real objects was superior to memory for matched images. In their study, participants were exposed to one of three stimulus conditions: real objects, colour photographs of the objects, or line drawings of the objects (altered from the original photograph). Across all conditions, the same orientation and approximate size of the stimuli were accounted for. Results indicated that memory for real objects was superior to memory for photographs, in terms of both recall and recognition.

Snow et al. (2014) proposed three possible explanations as to why memory for objects was better than memory for pictures. One explanation focused on the differences in visual cues. Real objects have the advantage of binocular cues, which provide the observer with a rich sense of depth and form when assessing the geometric structure. In the pictorial conditions, the participants did not have this advantage. Instead, participants in this condition were limited to monocular cues such as shading and texture which was insufficient to convey visual structure. Based on their findings, Snow et al. (2014) hypothesized that the difference in visual structure may be a possible factor contributing to the object memory advantage.

A second explanation suggested that real objects may be more memorable because they activate the dorsal stream at encoding. Real objects are tangible structures, whereas pictures are abstract representations that are harder to understand (DeLoache, Pierroutsakos, & Uttal, 2003). The dorsal stream is important because it considers the spatial locations of objects and influences our visual processing (Polanen & Davare, 2015). Graspable objects work closely with the dorsal stream network (Handy, Tipper, Borg, Grafton, & Gazzinga, 2006) and the dorsal stream regions have been recognized to be active during episodic memory (Vilberg & Rugg, 2008), working memory (Xu & Chun, 2006), and motor tasks (Chao & Martin, 2000). Snow et al. (2014) theorized that real objects may activate the dorsal stream more strongly at encoding; as a result, this may result in qualitatively different processing from pictures.

A final explanation, highly related to the second explanation, focused on the idea of object affordances. Affordances provide important cues about the potential actions that can be used with objects and are important for our conceptual knowledge (Glenberg & Kaschak, 2002). Motor affordances help us to encode relationships for how to use objects and facilitate action (Montesano, & Lopes, 2012). A major distinction between objects and pictures is that objects afford action. For example, a cup can be grasped by the handle or rim, but a picture of a cup offers less possibilities. In exploring Snow et al.'s (2014) plausible explanations, the goal of the present study was to further investigate affordances and whether motor system involvement facilitated enhanced memory for objects

Research suggests that affordances are important for object recognition. Helbig, Graf, and Kiefer (2006), found that affordances play a major role in perception. In their study, participants were primed for affordances. They were shown how a hand acted upon a blurred object. Participants were not exposed to the object; therefore, they only saw the motion and orientation of the hand. By looking at what the hand was doing, it activated the motor cortex. Thus, when the real object was seen, knowing how to act upon it was quicker because of the initial priming. The researchers suggested that the potential to act on the object was primed because the motor cortex was stimulated, and this facilitated object recognition. Other studies have lent similar support by suggesting that motor areas are responsive when people retrieve information for interactions with objects (Boronat et al., 2005). Collectively, these findings suggest that processing manipulable objects will activate regions in the brain associated with motor processing even when there is no explicit instruction to do so.

Affordances are referred to as action plans to be carried out by the motor system (Tucker & Ellis, 1998). For instance, Tucker and Ellis examined whether people automatically form a motor response when an object is presented. In the study, participants were presented with objects that had a clear left or right-hand affordance. For example, a frying pan situated on the left has a left-handle affordance. Their results found that participants responded faster when the affordance of the object was congruent with their hand (e.g., left hand object is congruent with a left-hand grasp). The findings suggested that when motor representations are activated they play an integrative role in encoding our memory for the object. Moreover, it demonstrated that people do not merely construct internal visuals of objects, but they are also processing and preparing to act on the objects.

Research suggests that manipulable objects can engage different motor regions without explicit instruction. For instance, Chao an Martin (200) found that there was increased activation in the premotor cortex when participants viewed manipulable objects relative to when they viewed non-manipulable objects. In their study, they looked to investigate the relationship with the left premotor cortex for manipulable objects and whether these graspable objects activated the posterior parietal cortex. Researchers used functional magnetic resonance imaging (fMRI) to investigate the neural responses that were responsible for viewing and identifying pictures. In the first part of the study, participants viewed a series of manipulable and non-manipulable objects. The objects were presented briefly for 2s. In the second part of the study, participants were again briefly presented with the objects and asked to silently name them. Results demonstrated that the left ventral premotor cortex responded specifically to the manipulable objects in both viewing and naming conditions, suggesting that ventral premotor activation influenced the retrieval of manipulable objects.

The main aim of the present study was to examine how motor system involvement enhanced memory performance for objects. The findings of Snow et al. (2014) suggested that visually perceiving affordances automatically leads to the activation of the motor system. Therefore, fully engaging the motor system with an action on the objects should lead to even better memory performance. During the study, stimuli was presented as either objects or pictures to the participants. At the time of presentation, participants completed a non-motor or motor judgement task. Overall, it was hypothesized that the study would replicate Snow et al.'s (2014) finding and demonstrate that objects were more memorable than pictures. In addition, the researcher hypothesized that motor system involvement would further enhance memory for objects but not pictures.

Method

Participants

Participants were 120 undergraduate university students recruited from the University of Regina's participant pool. All participants were randomly assigned to one of the four conditions. Prior to testing, the study was reviewed and approved by the University of Regina Ethics board and participants agreed to procedures outlined in the informed consent. An additional eight students were tested but excluded from the final sample for the following reasons: English was not the participants first language (N = 4), had prior knowledge that it was memory test (N = 1), a misunderstanding of stimuli in task phase (N = 1), and surpassed typical age range (N = 1). A final outlier, with a recall score exceeding three standard deviations of the mean was removed (N=1).

Stimuli

Stimuli consisted of 44 objects and 44 corresponding pictures of those objects. A list of the 44 objects can be found in Table 1. High resolution shots of the objects were used to produce photos consistent in object orientation and approximate size. The photos produced measured 8.5" x 10.5" in size.

In the object conditions, stimuli were presented on a customized foam core which used black electrical tape to section the board into four quadrants. Each quadrant held one object, yielding a total of four different stimuli per trail. In the picture conditions, a similar board was constructed with the additional feature of square wooden blocks used to prop the pictures up off the board. Two bins were constructed from cardboard and construction paper for containing the objects in the syllable judgement task. A green bin was designated for one syllable stimuli, and a yellow bin was designated for more than one syllable stimuli. For the writing conditions, participants were given response sheets that corresponded with the layout of the board. The participants job was to record their responses with the word ‘one’ or ‘more’ depending on how many syllables the stimuli had.

Procedure

The study used a 2 (objects vs. pictures) x 2 (motor vs. non-motor) between-subjects design. Thirty participants were randomly assigned to each of the four conditions. After providing informed consent, participants completed the task phase. In the task phase, participants were asked to sit on a revolving office chair and situate themselves in the direction of the table and foam board. Before each trial, the participant was asked to turn 180 degrees away from the board and face the back wall for 30 s, during which time the researcher had set up the board with four stimuli. A laptop computer emitted a sound which prompted the participant to turn back and face the table. Participants then determined if the word for the object or picture was one syllable or more than one syllable. Participants were shown 44 stimuli over the course of 11 trials. In the motor conditions, participants made their response by moving the objects into the appropriate bin: The green bin was for one syllable stimuli and the yellow bin was for more than one syllable stimuli. The position of the bins was fixed; therefore, the green bin always remained to the left of the participant, and the yellow bin always remained to the right of the participant. In the non-motor condition, participants made their response by writing the word “one” or “more” in the appropriate quadrant of the response sheet.

Once the 11 trials were complete, participants were presented with a distractor task where they listed as many US states within a period of 1 min. Once finished, memory for items in the task phase were examined through recall and recognition. For recall, participants were given a blank sheet of paper and asked to write down as many of the stimuli they could remember within a period of 5 mins. Following recall, in the recognition task participants were given a list of 88 items: 44 that were the familiar items and 44 that were unfamiliar items not presented in the task phase. Participants were asked to decide if they remembered seeing each item in the task phase, by checking *yes*, for previous items and *no,* for new items. At the end of the experiment, participants were debriefed and the intent of the study was made clear. The researcher explained how the overall purpose of the study was to examine how people remembered stimuli that they made judgements about.

Coding

Participants recall and recognition responses were evaluated as either correct or incorrect across the four conditions. For recall, stimuli that could be resolved from the description were counted as correct. For example, if a participant recorded *jar* instead of *bottle* the item would be marked as correct. For recognition, each participant's d-prime score was calculated by subtracting the number of false alarms (saying yes to stimuli that were not on the list) from the number of hits (saying yes to stimuli that were on the list). Recall and recognition responses were coded and reviewed again to ensure accuracy.

Results

For recall, a 2 (Stimuli: Object vs Picture) x 2 (Task: Motor vs Non-Motor) factorial ANOVA revealed a significant main effect for stimuli, $F(1,116) = 8.38$, $p < .005$, $\eta^2 = .07$. As hypothesized, participants in the object condition were significantly more accurate at reporting correct stimuli ($M = 16.37$, $SD = 3.57$) as compared to those in the picture condition ($M = 14.55$, $SD = 3.40$). There was no main effect for task, $F(1,116) = .68$, $p > .412$. There was a statistically significant interaction between stimuli and task, $F(1,116) = 4.63$, $p < .034$, $\eta^2 = .04$. The means for these conditions can be found in Figure 1. Independent sample t-tests were used to further evaluate the hypothesis that the motor task would show a significant improvement only for objects and not pictures. This hypothesis was also supported: object action (M = 17.30, SD = 2.90); object writing (M = 15.43, SD = 1.04). The difference between the means was statistically significant $t(58) = 2.08$, $p < .042$. Independent sample t-tests revealed no effects of picture on task: picture action (M = 14.13, SD = 3.49); picture writing (M = 14.97, SD = 3.31). Therefore, the difference between the means was not statistically significant $t(58) = -.95$, $p > .346$.

The same factorial ANOVA was used to assess false alarms, and similar results were generated. A main effect for stimuli was found $F(1,116) = 5.69$, $p < .019$, $\eta^2 = .05$. Participants in the picture condition reported more false alarms (M = .77, SD = 1.03) than those in the object condition (M = 0.37, SD = 0.82). There was no main effect for task $F(1,116) = .01$, $p > 1.00$. There was a statistically significant interaction between stimuli and task, $F(1,116) = 5.69$, $p < .019$, $\eta^2 = .05$. Thus, independent sample t-tests were used to further evaluate if the motor task would show reduced false alarms only for objects and not pictures. The hypothesis was generally supported in the object condition, as the difference between the means approached statistical significance, $t(58) = -1.93$, $p > .059$ but there was no significant difference in the picture condition $t(58) = 1.52$, $p > .134$. The means for these conditions can be found in Figure 2.

Finally, the same ANOVA was run on d-prime values from the recognition task. Some findings were similar for recognition but not all. The ANOVA revealed a significant main effect for stimuli, $F(1,116) = 23.81$, $p < .001$, $\eta^2 = .17$. As hypothesized, participants in the object condition were significantly more accurate at remembering correct stimuli (M = 3.26, SD = 0.55) as compared to those in the picture condition (M = 2.71, SD = 0.68). A main effect for task approached statistical significance $F(1, 116) = 3.56$, $p > .062$, $\eta^2 = .03$. Additionally, there was no statistically significant interaction between stimuli and task on recognition, $F(1,116) = p >$

.995. An independent sample t-test on object recognition revealed that participants had no advantage based on the task they were given: object action (M = 17.30, SD = 2.90); object action (M = 15.43, SD = 3.96). The difference between the means was not statistically significant $t(58) = 1.51$, $p > .136$. An independent sample t-test on picture recognition revealed similar results: picture action (M = 2.82, SD = 0.68); picture writing (M = 2.61, SD = 0.67). The difference between the means was not statistically significant $t(58) = 1.21$, $p > .233$.

General Discussion

The present study investigated whether involvement of the motor system could enhance memory for real objects. In the experiment, free recall and recognition were examined for real objects and matched pictures. The findings in this study replicated previous observations (Snow et al., 2014) demonstrating that objects were more memorable than pictures across all conditions. The results support the hypothesis that visually perceiving affordances leads to the activation of the motor system. More importantly, they showed that preforming actions on these objects improved recall.

As predicted, when asked to recall, participants in the object motor condition were significantly better at reporting stimuli relative to the object non-motor and picture conditions. Since objects offer affordances (Gibson & Walker, 1984), it is proposed that they unconsciously engaged the motor system when they were viewed. Therefore, when an object was acted upon, memory performance was enhanced because the motor system was further activated. Why does engaging the motor system lead to enhanced recall? One possible reason is that motor output is integral to cognition (Hommel, 2004). In line with theories of embodied cognition (Baraslou, 2010), the study demonstrated that visual perception and motor involvement improved recall. Motor simulation was evoked when participants observed visual characteristics of objects that afforded action. For instance, when a person observed a mug, it afforded action to be grasped by the rim or the handle. Whereas, in the picture conditions, the stimuli offered less possibilities for similar affordances. Memory in the object motor condition was also associated with fewer reports of false alarms; whereas, the opposite was found in the picture conditions. The difference between conditions is assumed to be attributed to the visual perception of objects and the role of the motor system. Individuals in the object-motor condition had the advantage of not only seeing the real objects, but further engaging the motor system by interacting with the stimuli. The findings of the present study suggest that the more engaged the motor system is, the richer the memory trace will be.

The object-motor interaction may be further explained by the role of multi-sensory encoding. Research suggests that the retrieval of information is richer when it involves multiple associations rather than when it is encoded individually (Craik & Tulving, 1975). For example, it is easier to remember what we had for supper when other characteristics of the same event can be remembered, such as the background music playing at the restaurant. Similarly, actions involved in the retrieval of information may play a similar role by producing cues that are connected to memory for stimulus information (Hommel, 2004). The study gave support in demonstrating that engaging multiple modalities contributed to richer representations of objects in memory. When participants visually perceived the affordances for the objects it activated the motor system. More significantly, they showed that facilitating action on those objects further improved their memory in recall. Similar studies have lent support to this finding by demonstrating that motor commands contribute to a richer representation of stimuli in memory (Trewartha, Case, & Flanagan, 2014). Trewartha, Case, and Flanagan (2014) examined the memory for the spatial location of objects by comparing passive interaction (a robot moves participant's hand to touch the target object) with active interaction (participant moves his or her hand to touch target object). Even though limb movement and object locality were consistent across all conditions, participants in the active condition had better recall of the target's location. Like the present study, the results suggest that the internal motor commands used to facilitate action contributed to a richer memory trace, which in turn, increased the likelihood of accurate recall.

In terms of recognition, again, memory for objects was enhanced relative to memory for pictures. However, unlike the recall measure, motor involvement did not significantly influence memory for objects. One interpretation of this finding suggests that in recognition participants were not relying solely on their memory. They were given cues to retrieve the stimuli; however, these cues may have primed inaccurate memories of similar stimuli (e.g., recalling a pen instead of a pencil) which resulted in poorer memory performance.

Limitations

One limitation of the current study may be some concerns regarding generalizability. The study used a limited age range of university students which makes it difficult to assess whether these results would be transferable to children or older adults. Another limitation of this study is the size of stimuli across conditions. The photos produced were consistent in object orientation but were only approximate in size. Therefore, in some cases the photos appeared much smaller than the matched objects (e.g., garden shovel). This lack of real-world presentation may have disadvantaged the participants in the picture conditions. A final limitation of the current findings would be a lack of real-world credibility. All measures for this finding were conducted in a lab setting. In a real-world situation, results would likely differ because people would be unaware that they were being assessed.

Conclusion

In conclusion, it was found that motor system involvement facilitated enhanced memory performance for real objects. Replicating Snow et al.'s (2014) finding the study also found that memory for objects was significantly better than memory for pictures. Based on these findings, it can be suggested that objects are stored, represented, and processed differently than pictures because they offer affordances for action. However, more research is required to further support these results. Future studies can look to sample different populations to ensure reliability and obtain results that are more representative of the larger population.

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Table 1 *Forty-Four True Stimuli*

Bottle	**Tennis Ball**
Ruler	**Rubber Duck**
Magnifying Glass	**Glasses**
Highlighter	**Comb**
Corkscrew	**Light Bulb**
Apple	**Tape Dispenser**
Flashlight	**Funnel**
Paint Roller	**Small Shovel**
Dice	**Shell**
Ladle	**Pizza Cutter**
Spoon	**Pencil**
Nail File	**Plate**
Bell	**Hairbrush**
Salt Shaker	**Book**
Toothbrush	**Cork**
Paintbrush	**Soap**
Oven mitt	**Lemon**
Pliers	**Hole Punch**
Hat	**Scissors**
Glove	**Calculator**
Rubber Spatula	**Sponge**
Screwdriver	**Mug**

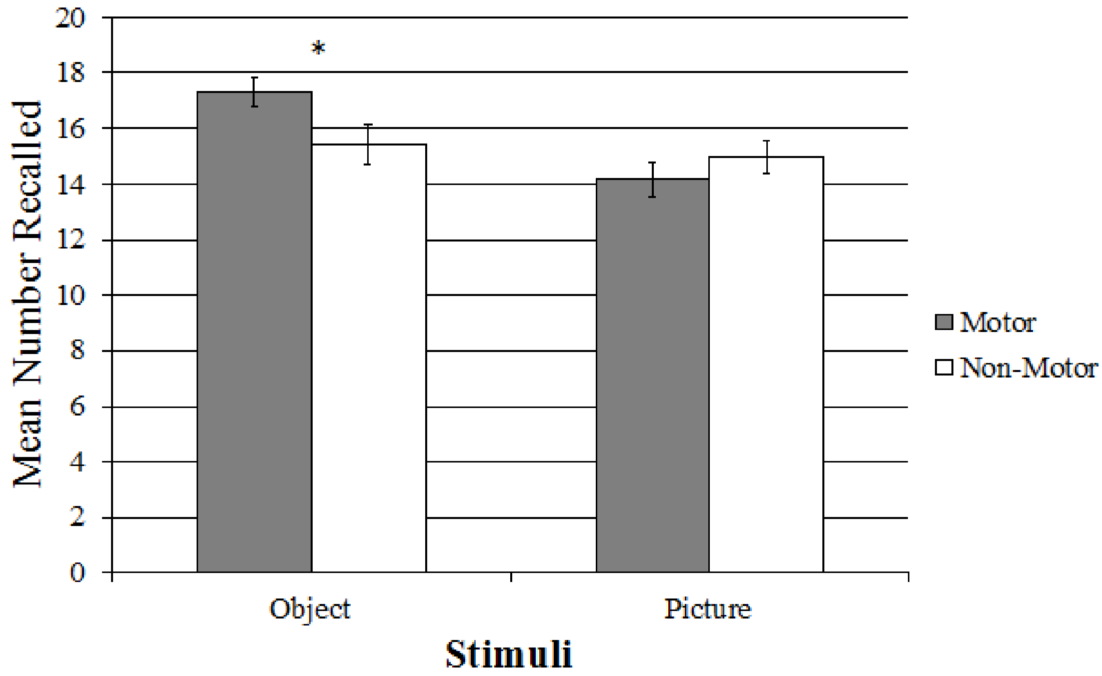

Figure 1. Mean number recalled as a function of stimuli (object vs. picture) and task (motor vs. non-motor). Errors bars represent standard error. The asterisk indicates significant interaction between object and motor-task.

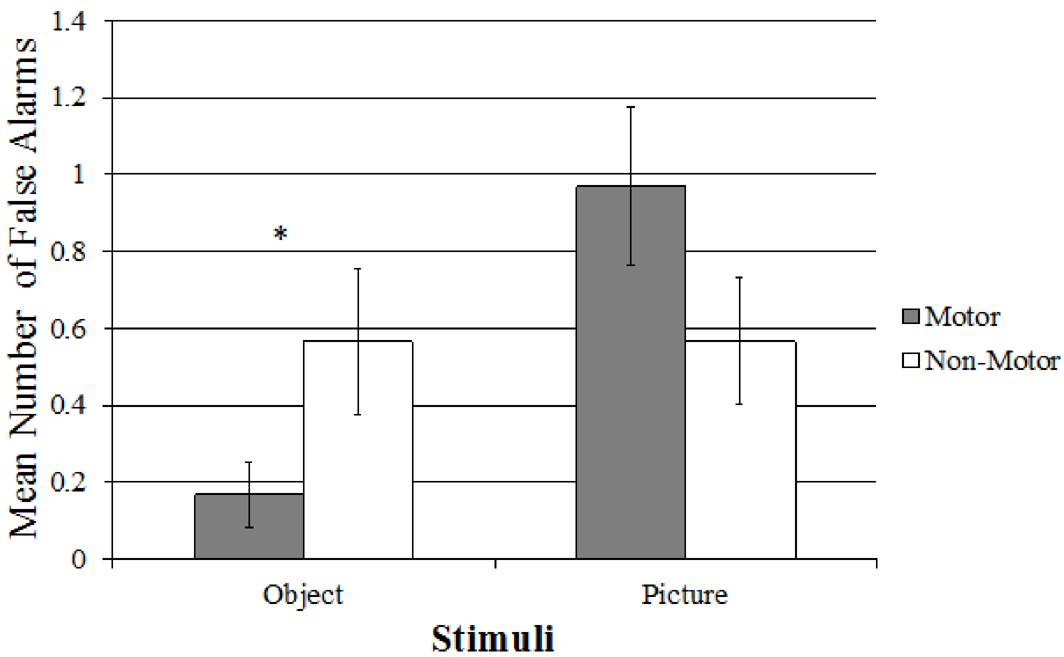

Figure 2. Mean number of false alarms as a function of stimuli (object vs. picture) and task (motor vs. non-motor). Errors bars represent standard error. The asterisk indicates significant interaction between object and motor task.