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# How Do Observer's Responses Affect Visual Long-Term Memory?

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How does responding to an object affect explicit memory for visual information? The close theoretical relationship between action and perception suggests that items that require a response should be better remembered than items that require no response. However, conclusive evidence for this claim is lacking, as semantic coherence, category size, and trial frequency often differ between stimuli that require a response and those that do not. Here we showed that memory is affected by response requirements, even when confounding factors were eliminated. Participants viewed a stream of images and encoded them into memory. During encoding, some images required a response, whereas others did not. Although all images were task relevant, images that were overtly responded to (e.g., with a button press) were better remembered than those that were not. However, the action itself was not critical to the memory advantage. Covertly counted images were better remembered than those that were not. Moreover, when participants pressed a button for most images, images that required withholding a button press were remembered better than the others. We conclude that the need to modify an ongoing activity results in improved memory.

*Keywords:* visual memory, response updating, action, semantic coherence

Many daily activities require people to respond to goal-relevant objects (Allport, 1989; Goodale & Milner, 1992; Hommel, 2004). The responses range from a simple reckoning of “yes” and “no” to planning and execution of complex motor actions. To what degree is visual memory for objects influenced by the response one makes while encoding them? More specifically, is memory for objects that one responded to superior to memory for objects to which no response was made?

It may seem apparent that the answer to this question is yes. Increasing evidence shows that responding to an object affects the way it is represented in memory. For example, the theory of event coding proposes that an event file is associated with a visual object, and this file contains information about the visual properties of the object as well as the planned or executed action toward it (Hommel, 2004; Hommel, Müssele, Aschersleben, & Prinz, 2001). This theory and the idea that perception and action are closely related have received strong support from behavioral (e.g., Buttaccio & Hahn, 2011; Craighero, Fadiga, Rizzolatti, & Umiltà,

1999; Tipper, Lortie, & Baylis, 1992), neuroimaging (e.g., Nobre, Gitelman, Dias, & Mesulam, 2000), and neurophysiological studies (Moore & Fallah, 2001). If objects that are acted upon are stored with codes indicating the response they elicited, then memory for those objects might be better than memory for objects without an action code.

However, a careful evaluation of existing studies on how responses affect object memory suggests that a conclusive answer is lacking. Responses are often confounded with other factors such as category size and semantic coherence. In this study, we first present experiments that carefully controlled for these variables. We then investigate the nature of the memory enhancement for images that are associated with a response.

## Response and Memory

Consider a study examining the impact of encoding requirements on object memory (Williams, 2010). Participants were shown a sequence of pictures of white cars (targets), non-white cars, other white objects, and non-white objects that were not cars. Participants counted the number of white cars in the sequence. Therefore, each object had to be processed to determine whether it was a white car; however, only white cars led to a response (i.e., a mental update of count). Later memory for white cars was 15%–30% higher than that for the other objects. It would seem that the response played a major role in object memory. However, other differences may also account for the memory advantage for white cars in this study. For example, white cars were less frequent than the other objects, potentially facilitating memory (Hunt & Lamb, 2001). Additionally, images that required a response fell into a narrow, semantically coherent category (“white cars”), whereas the other images were semantically incoherent: The only similarity between things like a computer, a pomegranate, and a tiger was that they were not white cars.

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Semantic coherence facilitates memory for words. For example, people remember *chicken* better than *table* after answering “Is \_\_\_\_\_ a kind of animal?” Craik and Tulving (1975) proposed that semantic coherence provided a strong memory retrieval cue. Animal is a more effective cue for retrieving *chicken* than *table*, because it is more strongly associated with *chicken* than with *table*. Additionally, recent work demonstrates that semantic information serves as a conceptual “hook” for remembering visual details (Konkle, Brady, Alvarez, & Oliva, 2010). Thus, semantic coherence may have contributed to better memory for objects that required a response than for those that did not.

When semantic coherence and trial frequency are equated, there is little evidence that responding to a verbal or visual stimulus enhances learning and memory. For example, when asked to say “yes” to all blue words in a list of blue and white words, participants remembered the blue and white words equally well (MacLeod, Gopie, Hourihan, Neary, & Ozubko, 2010). Similarly, when participants pressed a key for blue words and made no response to white words, memory for the blue and white words was similar (MacLeod et al., 2010, Experiment 4). Responses to words appear to enhance memory only when the response to the word is distinctive. When people read aloud or mouthed words presented in blue and silently read words presented in white, they remembered the blue words 10%–20% better than words read silently (MacLeod et al., 2010). This “production effect” suggests that word memory is enhanced when a response is individualized and related to the memory item, resulting in a distinctive memory trace for each word that elicited a response. Distinctive responses are also needed to produce the “enactment effect,” where memory for verbal instructions is better if people act out the instructions rather than just read them (Engelkamp, 1997; Zimmer & Engelkamp, 2003). It appears that memory for a verbal event can be strengthened if each event contains a distinctive response code, but memory is unaffected if the response code is not individualized.

There are also reasons to believe that responses could affect the perception and memory of visual materials (Hommel, 2004; Roberts & Humphreys, 2011). In particular, studies of spatial attention suggest that regions near the hands are prioritized in search (Abrams, Davoli, Du, Knapp, & Paull, 2008; Reed, Grubb, & Steel, 2006). However, as with verbal materials, the mere need to respond to visual stimuli has no consistent impact on learning and memory. For instance, in a study of contextual cuing (cf. Chun & Jiang, 1998), people were asked to search for a *T* among *L*s and press a key for some displays (such as those with a left-tilted *T*) and make no response for others (Makovski & Jiang, 2011). Unbeknownst to participants, the search displays repeated occasionally. In a subsequent visual search session that required responses to all targets, targets were found more quickly when they were in repeated displays rather than in new displays. The amount of learning, however, was not affected by whether the displays were previously associated with an immediate overt response or not.

In sum, although it may seem that memory should be influenced by whether one responded to or acted on a stimulus, evidence for this idea has been mixed. If a response is individualized for each encoding stimulus, then memory is enhanced. But if the response is the same for all stimuli that received a response, then it does not strengthen memory. This pattern of results may be incorporated into the theory of event coding (Hommel et al., 2001), assuming

that the event files become more distinctive when they contain individualized response codes.

## The Present Study

Presently, there is little evidence that a response, in and of itself, is sufficient to enhance memory, particularly for visual objects. The first goal of the present study was to provide such evidence. The results of Experiment 1 showed a clear memory advantage for images that required a response over images that did not. Subsequent experiments aimed to distinguish several theoretical accounts of this observation: (a) The *category coherence account* suggests the memory advantage for images receiving a response results from their shared visual features and greater perceptual coherence. (b) The *action account* suggests that the motor act of pressing a button produces an action code that enhances memory. (c) The *temporal updating account* postulates that the cognitive processes triggered by images that require a change in ongoing activity enhance visual memory.

## Experiment 1

In Experiment 1, we tested whether memory for a visual stimulus is influenced by the need to make an immediate response. Importantly, the response requirement did not vary with trial frequency and category size. Participants viewed a series of individually presented male and female faces that appeared with equal frequency. They pressed a button whenever the image was female (or male for half the participants). Unlike studies on the production effect or the enactment effect, the response was the same, rather than individualized, for all images that received a response. In addition, participants’ hands were on the keyboard throughout the experiment; there were no differences between responded and unresponded stimuli in terms of body position. These stringent conditions increased the opportunity to isolate an effect of response on explicit memory for visual materials.

If memory is strengthened only when individualized response codes exist for different events, then stimuli that received the same response (e.g., press the spacebar) should not be remembered any better than stimuli with no response. However, if responding to a stimulus has a more general effect on memory, then faces that were responded to should be better remembered than faces that were not.

## Method

**Participants.** Students from the University of Minnesota participated in this study for extra course credits or for \$5. They were 18–33 years old and had normal or corrected-to-normal visual acuity. There were 40 participants in Experiment 1 with a mean age of 19.5 years.

**Equipment and stimuli.** Participants were tested individually in a room with normal interior lighting. They sat unrestrained about 55 cm away from a 19-in. CRT monitor. The experiments were programmed with Psychtoolbox (Brainard, 1997; Pelli, 1997), implemented in MATLAB ([www.mathworks.com](http://www.mathworks.com)).

The stimuli comprised 544 gray-scale images of front-view faces of human adults, including celebrities, sports figures, politicians, and unfamiliar people. Half the famous and half the unfa-

miliar people were males, and the other half were females. Famous and unfamiliar faces each have an advantage: Unfamiliar faces do not have prior memory nodes. Using them would minimize the impact of semantic knowledge. However, memory for unfamiliar faces is quite poor and may suffer from a floor effect. Using famous faces allowed us to bring memory performance to a reasonably high level, increasing the sensitivity of the design.

**Procedure and design.** During the *encoding phase* (about 15 min), participants viewed a randomly selected series of 272 faces with a balanced composition of males and females and famous and unfamiliar people. Each trial started with a black fixation point ( $0.4^\circ \times 0.4^\circ$ ) for 500 ms, followed by a centrally presented face ( $9.6^\circ \times 9.6^\circ$ ) for 400 ms, and then a multicolored mask for 600 ms (see [Figure 1A](#)). The next trial started immediately after that, producing a continuous stream that paused every 34 trials for a break. Participants pressed the spacebar as soon as they detected a face of a specific gender and made no response to faces of the other gender. The gender associated with a response was counter-balanced across participants. During the break, participants were informed about their detection accuracy and response time (RT).

To examine whether the effect of response on memory interacts with an intention to remember, we included a factor of incidental versus intentional encoding ([Hyde & Jenkins, 1973](#); [Williams, 2010](#)). Before the encoding phase, half the participants were told that their memory for all of the faces would be tested. The other half simply performed the gender detection task. All participants completed the recognition phase.

During the *recognition phase*, memory for all 272 faces was tested in a random order using a two-alternative forced-choice (2AFC) procedure. On each test trial, two faces of the same gender were shown side by side. One face was an old face and the other was a foil (see [Figure 1B](#)). Whether the old face was on the left or right side was randomized. The foil for a famous face was also famous, and the foil for an unfamiliar face was also unfamiliar. Participants pressed one of two keys to report whether the face on the left or the one on the right was old. Trial-by-trial feedback was displayed in the form of a green plus or a red minus for 500 ms.

## Results

During the encoding phase, participants quickly (mean RT = 385 ms,  $SE = 5$  ms) and accurately responded to faces in the target

gender 98.8% of the time ( $SE = 0.2\%$ ; *hits*). They correctly withheld a response to faces of the other gender 95.1% of the time ( $SE = 0.6\%$ ; *correct rejections*). We examined whether memory for images encoded with a hit (“button press”) was higher than memory for images encoded with a correct rejection (“no button press”), and whether memory was affected by the nature of encoding (incidental or intentional). Images that were incorrectly responded to (misses and false alarms) were excluded from the recognition memory analysis. [Figure 2](#) shows the results.

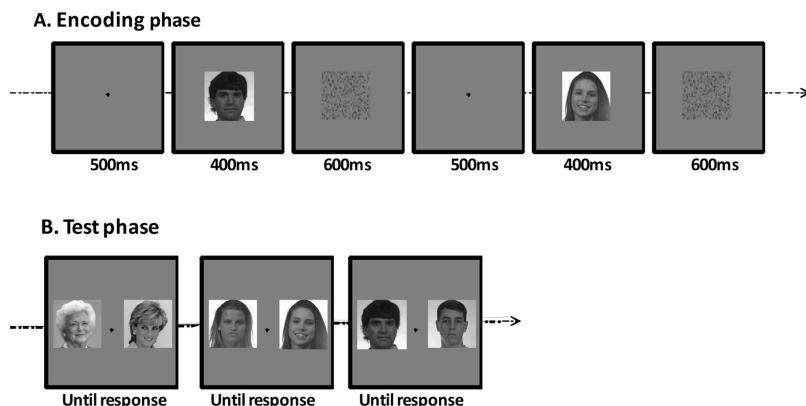
A repeated measures analysis of variance using intention to remember and response requirement as factors revealed no effect of an intention to remember the images ( $F < 1$ ), and no interaction between intention and response requirement,  $F(1, 38) = 1.01, p > .50$ . Both groups were required to orient attention to and process the faces to perform the gender classification task. The data suggest that this task resulted in a memory trace that was not further strengthened by an intention to remember the faces ([Schacter, 1996](#)) and are consistent with earlier findings in the verbal ([Hyde & Jenkins, 1973](#)) and visual ([Williams, 2010](#)) domains.

Importantly, we found a significant main effect of response requirement,  $F(1, 38) = 10.55, p < .002, \eta_p^2 = .22$ . Images that received an immediate button press were better remembered than those that did not. This pattern of results did not interact with whether the faces were famous or unfamiliar ( $F < 1$ ). The [Appendix](#) provides separate memory recognition results for famous and unfamiliar faces.

## Discussion

Experiment 1 presents evidence that the need to make an immediate response produces a statistically significant gain in visual memory. The benefit was modest, 3.4%, several times smaller than the gain previously reported for a search target ([Williams, 2010](#)). However, the frequency and category size of the responded and unresponded stimuli were equated. The effect was also smaller than the production effect ([MacLeod et al., 2010](#)) or the enactment effect ([Engelkamp, 1997](#)). However, it was observed when the same response was produced for all images that received a response, a condition that failed to reveal a significant production effect in words ([MacLeod et al., 2010](#), Experiment 4).

Might the advantage for responded faces reflect a confirmation bias? In a task that required pressing a key for female faces, for



*Figure 1.* A schematic illustration of the encoding phase (top) and test phase (bottom) used in Experiment 1.

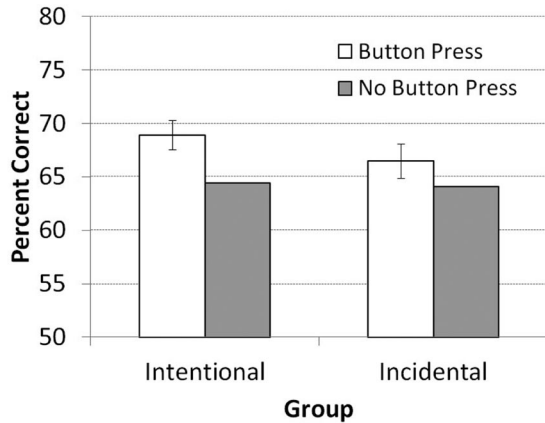


Figure 2. Results from Experiment 1's memory task. Error bars show  $\pm 1$  SE of the difference between the responded to (button press) and no-button press images.

example, each face that was a female confirmed what people were looking for. To examine whether confirmation alone affects memory, in a follow-up experiment 42 participants decided whether a face shown to them was of a specific gender. They pressed the *yes* key if it was the gender they were looking for and the *no* key if it was not. Results showed that faces receiving a “yes” response ( $M = 67\%$ ) were not better remembered than faces receiving a “no” response ( $M = 68\%$ ;  $p > .10$ ). This finding is consistent with an earlier study showing no general confirmation bias in memory when the “yes” and “no” categories are matched in size (Craig & Tulving, 1975).

### Experiment 2

One explanation for the memory benefit for stimuli that were responded to relates to category coherence (category coherence account). In particular, all male faces share a “maleness” feature, which can be morphed continuously to create a gender neutral face, and further to produce a prototypical female face (Webster, Kaping, Mizokami, & Duhamel, 2004). Because a single visual feature characterized all members of a category (e.g., males) in Experiment 1, people may have searched for that feature (e.g., maleness) without processing its counterpart (e.g., femaleness) in the faces that did not receive a response. This encoding difference, derived from the perceptual coherence of a given category, may have resulted in higher accuracy for responded faces.

To evaluate the category coherence account, in Experiment 2 we minimized the category coherence of the stimuli that received a response. Pictures of common objects were shown on the screen. They all extended the same visual angle on the screen. Participants were asked to press a button for objects that in reality would be larger (or smaller, for half the participants) than a basketball, and make no response to other objects. Both categories—responded images and unresponded images—were semantically incoherent and visually diverse. Under these circumstances, the category coherence account predicts that memory should be equivalent for responded and unresponded stimuli.

### Method

**Participants.** Thirty-six new participants (mean age 21 years) completed Experiment 2.

**Equipment, stimuli, procedure, and design.** A set of 360 color pictures of common objects was acquired from Aude Oliva's memory database (<http://cvcl.mit.edu/MM/>). All images subtended  $9.6^\circ \times 9.6^\circ$  and appeared at the center of the screen. Participants viewed a randomly selected set of 176 pictures, half of which depicted objects that in reality were smaller than a basketball (e.g., a coin, a paintbrush), and the other half depicted objects bigger than a basketball (e.g., a tire, a bear). Participants encoded all objects for a memory test. In addition, they pressed the spacebar for objects larger (or smaller, for half the participants) than a basketball, and made no response to other objects. The objects remained on the screen for 1 s before the next trial started. Other aspects of the experiment were the same as in Experiment 1.

### Results

During the encoding phase, participants correctly pressed the button in response to 93.5% of the target images ( $SE = 0.6\%$ , hits), with a mean RT of 549 ms ( $SE = 8.7$  ms). Participants correctly withheld a response for 92.9% of the other objects ( $SE = 0.7\%$ , correct rejections).

As in Experiment 1, explicit memory for objects that required a button press ( $M = 94.3\%$ ,  $SE = 0.9$ ) was significantly better than memory for objects that did not ( $M = 91.9\%$ ,  $SE = 0.9$ ). The magnitude of the difference was small, 2.4%, but consistent across participants,  $t(35) = 2.30$ ,  $p < .03$ , Cohen's  $d = 0.46$ . Thus, even in an experiment in which the responded objects were highly diverse in visual features and were semantically incoherent, the need to respond to an object increased memory accuracy. This finding does not support the category coherence account, and instead suggests that the memory benefit derives from the response requirement.

It is notable that overall memory accuracy in this experiment was high—over 90%. This level of memory performance for everyday objects had been reported previously, suggesting that visual long-term memory for objects is very high in capacity (Brady, Konkle, Alvarez, & Oliva, 2008; Konkle et al., 2010).

### Experiment 3

The results of Experiments 1 and 2 are unique because they reveal a memory benefit for images that participants responded to, even in the absence of individualized responses. Without individual action codes, the potential processing differences for images that were responded to and those that were not is relatively small. However, the response requirement effect was consistent. What could have produced the memory gain for images that people responded to?

At first blush, the results from Experiments 1 and 2 could be considered as another demonstration of how action matters in perception (e.g., encoding). According to the action account, memory is enhanced when an overt action is produced in response to an image (Buttaccio & Hahn, 2011). That is, because all images had to be attended and processed to nearly the same extent (up to the stage of making a semantic decision), the critical difference be-



tween responded to targets and nontargets is that an overt motor action was required only for the former. A potential mechanism for such an advantage could be the inclusion of an additional code in the event file created for images that are acted on relative to event files created for images that lack an overt action (Hommel, 2004).

However, it is also important to consider other ways in which the response and no-response conditions differed in Experiments 1 and 2. Prior to the appearance of an image, no response was planned.<sup>1</sup> But once an image was identified as the appropriate category (e.g., male), participants needed to update the current goal representation and make an appropriate response. Temporal updating might initiate additional cognitive processes (e.g., target verification, response implementation) that enhance and deepen image processing. These processes would not be involved in processing images that do not require a response. Thus, a second account (temporal updating account) emphasizes the fact that images that require a response change the participant's cognitive and goal states.

To examine whether the memory benefit for responded to items is due to the action, or whether it is more appropriately attributed to temporal updating, participants in Experiment 3 were asked to count images in a particular category and to not respond to images in the other category. As in Experiment 1, participants encoded a stream of individually presented male and female faces into memory. In addition, they kept a mental count of the number of males (or females, for half of participants) that were presented within a block of trials. A memory benefit for counted faces would be consistent with the temporal updating account and would suggest that an overt action is not necessary for the memory benefit.

## Method

**Participants.** Twenty new participants completed Experiment 3. Their mean age was 21 years.

**Design.** The experiment was similar to Experiment 1's intentional encoding group. Participants were told to remember all faces for a subsequent memory test. In addition, they were asked to keep a silent count of the number of faces in a specific gender, counterbalanced across participants. The count was probed after every eight faces. The experiment was otherwise identical to Experiment 1.

## Results and Discussion

Participants were highly accurate in the covert counting task, with a mean accuracy of 94% ( $SE = 1.5\%$ ). The majority of the errors (over 90%) were off by one count.

Even though counting was covert, it produced the same effect as an overt button press response (see the [Appendix](#) for famous and unfamiliar face results). Faces that were counted ( $M = 68.8\%$ ,  $SE = 1.3$ ) were better remembered than those that were not counted ( $M = 63.9\%$ ,  $SE = 1.9$ ),  $t(19) = 4.16$ ,  $p < .001$ , Cohen's  $d = 0.67$ . This advantage (4.9%) was comparable to the one found in Experiment 1 ( $F < 1$ ), suggesting that it does not depend on the need to execute an overt motor action.

As with an overt button press, the requirement to respond to an image by incrementing an internal count enhanced memory for the image. These data clearly show that an overt manual response to an image is not necessary to produce the memory enhancements

observed in Experiments 1 and 2. Thus, any form of response updating may be sufficient to enhance memory, regardless of the overt or covert nature of the response. Experiment 4 provides a more stringent test of this proposal.

## Experiment 4

Experiment 3 demonstrated that a response, even a covert one, is sufficient to produce a memory advantage for images in the target category. Although these data clearly show that an action is not necessary for the memory benefit, one could claim that mentally counting the items also produces an action code that is incorporated into an event file, and thereby enhances memory. In contrast, the temporal updating account suggests that it is a change in the participant's goal state that leads to enhanced memory. Changing one's goal state may lead to the production of an action (such as a button press) or it could lead to the interruption of activity (such as when one expects to act on all items but the ones in the target category).

The final experiment more strongly contrasts the action and temporal updating accounts by testing whether items that modify a participant's activity, even those that cancel an action, enhance memory. Participants were asked to press a button for all images. However, they were told to withhold a button press for certain types of images. The action account predicts that images associated with a button press will be remembered better than images without a button press. The temporal updating account predicts that images associated with the cancelation of a planned button press will be remembered better.

We carried out a pilot study in an attempt to disassociate response and action from temporal updating via task instructions.<sup>2</sup> Participants were told that they should press the button as quickly as possible to all images. They were also told that they should cancel the button press when faces of a specific gender (e.g., females) appeared. However, participants reported that this instruction was confusing and that they resolved it spontaneously by flipping the task instructions. Instead of pressing the button for all but female faces, all participants reported that they treated the instruction of "withholding a response to female faces" as "responding to male faces." The pilot data suggested that, all else being equal, people tend to treat no response as the default mode of action.

To ensure that participants planned a button press for all images, we added a third category of stimuli in Experiment 4. Participants viewed a stream of individually presented images from equally frequent categories: male faces, female faces, and scenes. Participants were told to press a button for all images except faces of a specific gender (e.g., male faces). This manipulation encouraged participants to plan a button press for all images but to cancel the planned action for those in the prespecified category. The action account and the temporal updating account make opposite predictions about whether memory should be better for faces associated

<sup>1</sup> Given the equal frequency of the two types of images, this account assumes that participants' default was to make no response whenever an image appeared. We present evidence from a pilot experiment that supports this assumption in Experiment 4.

<sup>2</sup> We thank Geoff Woodman for suggesting this experiment.

with a motor action or for faces that led to the cancellation of a planned motor action.

## Method

**Participants.** Twenty new participants completed Experiment 4. Their mean age was 24 years. Data from one of the participants were excluded because overall accuracy in the encoding phase was below 65%.

**Equipment, stimuli, procedure, and design.** This experiment was similar to Experiment 1's intentional encoding condition except for the following changes. Participants viewed a randomly selected series of 204 images. The images were equally likely to be natural scenes, famous males, and famous females. The images were presented in a random order. Participants were told to remember all items for a subsequent memory test. In addition, they were told to press the spacebar as quickly as they could upon the onset of an image, except when the image was a face of a specific gender. The gender to which a response was withheld was male for 11 participants, and female for the other participants. Memory for all images was tested in the 2AFC task as described in Experiment 1.

## Results and Discussion

Hits were trials on which people pressed the spacebar when they were supposed to. The hit rate was nearly perfect: 99.7% for scenes ( $SE = 0.2\%$ ) and 99.3% ( $SE = 0.3\%$ ) for button press faces. Hits RT was also very fast: 374 ms for scenes ( $SE = 11$  ms) and 397 ms ( $SE = 11$  ms) for button press faces. In addition, *correct rejections* were defined as trials on which participants successfully withheld a button press. The correct rejection rate was 79.3% ( $SE = 2.4\%$ ), notably lower than in previous experiments ( $p < .01$  compared with Experiment 1). A lower correct rejection rate in this experiment is expected if participants followed the instructions and planned a button press for all images. On a substantial proportion of trials (more than 20%), they did not stop in time, allowing the planned action to go forward and resulting in a false alarm. Consistent with this possibility, responses were reliably faster for false alarms (349 ms,  $SD = 50$  ms) than for hits (397 ms,  $SD = 48$  ms),  $t(18) = 6.45$ ,  $p < .001$ . As in previous experiments, faces that were incorrectly responded to (e.g., misses and false alarms) were excluded from the analysis of recognition memory.

Figure 3 shows memory performance for scenes, button press faces, and no-button press faces. Memory for scenes was lower than that for faces,  $F(1, 57) = 8.7$ ,  $p < .01$ , consistent with previous reports (Brady, Konkle, & Alvarez, 2011). The critical analyses, however, focused only on the faces. According to the action account, hits, which were faces that led to a button press, should be better remembered than correct rejections, which were faces that did not lead to a button press. In contrast, because faces that required no button press led to a change in the participant's planned response, the temporal updating account predicts better memory for correct rejections than for hits.

Consistent with the temporal updating account, memory was better for the no-button press faces (correct rejections) than for the button press faces (hits),  $t(18) = 2.08$ ,  $p = .05$ , reversing the pattern shown in Experiment 1. A direct comparison with Exper-

iment 1 revealed a significant interaction between face type (button press or no button press) and experiment,  $F(1, 57) = 13.9$ ,  $p < .001$ ,  $\eta_p^2 = .20$ . This reversal clearly indicates that the key to enhanced memory in Experiments 1–3 was not whether an action was made, but whether a response was modified.

An important feature of the analysis of Experiment 4 was that only trials in which an action was successfully withheld were included in the memory analysis. This ensured that the division of hits and correction rejection was uncontaminated by false alarms. However, one could argue that the high rate of false alarms suggests that faces in the no-button press condition were processed differently than those in earlier experiments. Could this possibility complicate the interpretation of Experiment 4? We do not think so. A high false-alarm rate would make the images that do not require a button press more like those that do. As a result, the difference between the button press and no-button press conditions should decrease along with the likelihood of finding any significant difference in Experiment 4.

Another concern resulting from the high false-alarm rate is that it introduces the potential for a selection artifact. Specifically, the high hit rate (99%) means that all images receiving a keypress were included, but the moderate correct rejection rate (79%) means that only some images requiring a response update were included. A selection artifact could arise if faces that led to false alarms were more difficult to encode and remember than faces that led to a correct rejection. However, an item analysis indicated that false alarms were widely distributed across images, with the vast majority (99.6%) associated with just zero to three false alarms (62.5% with one to three false alarms). In addition, images associated with false alarms and correct rejections for one person were associated with hits for others. As a result, it was possible to examine memory accuracy for images that were associated with hits for one group of participants as a function of whether the image was associated with a false alarm in the other group of participants. There was no relationship: For people who correctly pressed a button in response to the images, memory accuracy was not higher for images that were associated with more false alarms in the other group ( $p > .25$ ). Thus, selection artifacts could not account for data from Experiment 4.

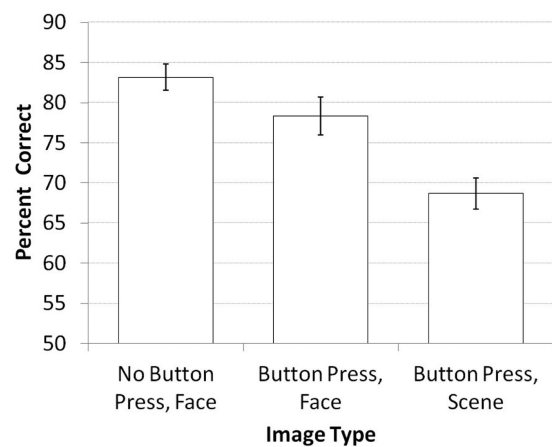


Figure 3. Memory performance for the three conditions tested in Experiment 4. Error bars show  $\pm 1$  SE of the mean of each condition.

Given the close relationship between action and perception, one might wonder why visual memory is relatively insensitive to whether or not it is associated with an action. One plausible answer is that images are tagged in memory with action-related information even when no action or response is required. They may be tagged with a code indicating which action was carried out on it, or tagged with a code indicating that no action was carried out (Kühn & Brass, 2010). Consequently, the event files (Hommel et al., 2001) may not differ qualitatively for images receiving an overt action and images that do not.

### General Discussion

Theoretical perspectives have long tied perception and action, suggesting that the way visual objects are encoded is strongly influenced by the actions that they support and that are performed on them (Allport, 1989; Barsalou, 2008; Hommel, 2004; Milner & Goodale, 2006). One consequence of the close relationship between perception and action may be that objects that are acted upon are better encoded into memory. In fact, when an encoded item is associated with an individualized action code, memory for the item is superior to that for items that received no response (Engelkamp, 1997; Förster & Stark, 1996; MacLeod et al., 2010; Zimmer & Engelkamp, 2003). However, evidence that any action, even one that is not unique, enhances memory was previously lacking. The present study demonstrates that generating a response can influence memory even when the responses are not unique. The enhancement associated with response generation was numerically small, less than 5% in all four experiments. Nonetheless, by controlling for category size, trial frequency, and other confounding factors, this study provides convincing evidence that response requirements have a general influence on memory. Moreover, it demonstrates that these enhancements are not specific to overt actions, but can be more broadly construed as reflecting processes that are engaged when an item requires a change in one's planned activities.

The memory advantage for items that modified a response cannot be attributed to a confirmation bias (Craik & Tulving, 1975). In a follow-up to Experiment 1, items that received a "yes" response were not remembered better than those receiving a "no" response. Moreover, the advantage was not limited to situations in which the responded and unresponded images fell into coherent perceptual categories. It was found even when the categories were arbitrarily defined, and items within each category were semantically incoherent and perceptually diverse (Experiment 2). We further showed that overt motor actions were not critical for producing the memory benefit. A covert response was just as effective (Experiment 3). Finally, withholding a planned motor response enhances memory relative to executing a planned motor response (Experiment 4). These data rule out overt action itself as the source of the memory advantage. Instead, it argues in favor of a temporal updating account. Images that call for the modification of a planned response are better remembered than those that do not, regardless of whether the response entails an overt motor response, covert mental updating, or withholding a planned motor response.

Our study suggests that the cognitive processes associated with temporal updating affect memory. According to this account, images that indicate that a response is required (i.e., by requiring

a change in one's planned activities) trigger additional cognitive processes that facilitate the encoding of that image into memory. It has long been known that target detection is more demanding than distractor rejection (e.g., the attentional dwell time; Duncan, Ward, & Shapiro, 1994). Indeed, it is a relatively straightforward task to list the additional processes that are likely to be engaged for such images (e.g., verification of the image as a target and implementation of the response itself). However, the mechanism by which the cognitive processes associated with response generation actually facilitates memory for the item is unknown. Multiple related and nonexclusive possibilities exist. One possibility is that the advantage occurs after the images have been perceptually processed. For example, as a part of temporal updating images that require a response may be stored in working memory and the long-term memory trace of the images consequently strengthened (Baddeley, 2012). Another possibility is that images requiring a response are processed more deeply and variably, resulting in levels of processing effect (Craik & Lockhart, 1972).

It is also possible that the advantage reflects greater attention to perceptual information that coincides with behaviorally relevant events. This notion is consistent with the theoretical framework of a related phenomenon, the attentional boost effect (Swallow & Jiang, 2010, 2011). In the attentional boost effect, people encode images into memory while simultaneously monitoring a stream of centrally presented black squares for occasional white squares. Although the color stream is unrelated to the image stream, images presented with target squares are typically remembered 10%–20% better than images presented with distractor squares, regardless of whether the targets require an overt or covert response (Swallow & Jiang, 2012). It has been proposed that detecting a target in the color stream produced a brief orienting of temporal attention to the moment when the target appeared (Swallow & Jiang, 2010, 2011). Similarly, in the present study, it is conceivable that the detection of images requiring a response produced a transient orienting of temporal attention.

Despite the similarities to studies on the attentional boost effect, the magnitude of the memory benefit in the present experiments is much smaller (2%–5% as opposed to 10%–20%). In the present study, what participants responded to was also what they were trying to remember. In contrast, in studies on the attentional boost effect, background images were encoded as participants performed an unrelated detection task. It is possible the temporal updating effect is magnified when participants attend to more than one stimulus stream. Under these resource-limited conditions, the sensitivity of the memory measure to slight changes in encoding conditions may increase.

Although these data are consistent with reports of enhanced memory for perceptual information that coincides with targets, they do raise the question of why similar enhancements have not been observed by others. MacLeod et al. (2010) failed to observe an enhancement for words that received a verbal ("yes") or manual (spacebar) response. However, MacLeod et al.'s manual response yielded a sizable, albeit insignificant, memory advantage (6.5%). Their verbal response may have interfered with subvocal articulation of the words, canceling out an effect of updating. Makovski and Jiang (2011) failed to detect any enhancement to contextual cuing for displays that received a manual response. However, as an implicit learning mechanism, contextual cuing may be less sensitive to subtle changes in attention than measures of explicit mem-



ory. Due to its modest size, the memory advantage associated with temporal updating may depend on the sensitivity of the memory measure.

Finally, throughout the article, we have considered the temporal updating effect as reflecting an enhancement for images that received a response. However, because there was no baseline measure of memory in these experiments, it is also possible that the effect reflects the suppression of images that received no response (Logan, 1988; Verbruggen & Logan, 2008). Indeed, a recent study found that shapes presented at the same time as a cue to withhold a response (“no-go”) were rated less positively than both novel shapes and shapes presented at the same time as a “go” cue (Buttaccio & Hahn, 2010). Although these data may suggest that suppression of images that receive no response underlies the effect, it is important to note that the go and no-go trials differed in category size and trial frequency. Thus, it is not clear whether the observed suppression generalizes to a stringent test of response requirements. More importantly, although the present study provided no baseline to assess enhancement and suppression,<sup>3</sup> a suppression account would predict better memory for “go” images than “no-go” images in Experiment 4, which was inconsistent with our data. Rather, the data were consistent with the claim that images requiring a change in response were better remembered than those that did not.

In summary, using a stringent design in which we controlled for category size, semantic coherence, and trial frequency, we have isolated an effect of response on explicit memory of visual materials. Memory was significantly better for images that required a response than for images without such a requirement. Although this effect demonstrates the impact of response requirements on memory, we have found no evidence to suggest that motor action affects visual memory. Instead, we argue that the need to modify an ongoing activity results in improved memory. The durability of this enhancement and whether it can be found in other memory paradigms are important questions to test in the future.

<sup>3</sup> In one attempt to provide such a baseline, participants were told only to remember the images, and were not given any instructions on whether to respond to the images. Recognition accuracy was similar to the responded-to images. However, because this experiment did not include a secondary task instruction, performance on this task is expected to be better than baseline performance on a task that includes a secondary task.

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## Appendix

### Mean Memory Accuracy for Famous and Nonfamous Faces in Experiments 1 and 3

	Famous		Nonfamous	
	Response	No response	Response	No response
Experiment 1	75.4% (1.8)	70.6% (1.8)	60.0 (1.3)	57.9 (1.2)
Experiment 3	76.0% (2.5)	69.6% (3.1)	61.1% (1.1)	58.2% (1.6)

*Note.* Standard errors appear in parentheses.

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