Photographic Memory:

The Effects of Volitional Photo-Taking on Memory for Visual and Auditory Aspects of an Experience

Alixandra Barasch[1]

Kristin Diehl[2]

Jackie Silverman[3]

Gal Zauberman[4]

Author Affiliations:
[1]New York University

[2]University of Southern California

[3]University of Pennsylvania

[4]Yale University

All four authors contributed equally to this article. Authorship order is alphabetical. Correspondence should be addressed to any of the authors.

All authors contributed to the study design. Data collection was performed by J.S., assisted by A. B. and research assistants in the field. J.S. performed the data analysis in consultation with the other authors. All authors drafted the manuscript and approve of the final version of the manuscript.

Abstract

How does volitional photo-taking impact unaided memory for visual and auditory aspects of experiences? Across one field and three lab studies in which participants could freely take photographs during an experience, we find that, even without revisiting any photos, participants recognize more of what they saw and less of what they heard, compared to those who cannot take photographs. We further show that merely taking *mental* photos has similar effects on memory as actually taking photos, providing support for a photography-induced shift in attention towards visual aspects and away from auditory aspects. In line with this mechanism, participants with a camera have better recognition of objects they photograph, compared to objects they do not photograph. Furthermore, participants who use a camera during their experience recognize even un-photographed objects better than participants without a camera. Meta-analyses across all reported studies further support these findings.

Keywords: memory, photographs, experiences, recognition

Photo-taking has become ubiquitous across experiences (Okabe & Ito, 2003). An important reason people take photos is to capture fleeting moments to remember later (Lux, Kogler, & del Fabro, 2010). While revisiting photos may help cue past memories (Koustaal et al., 1998), people actually rarely review their photos (Whittaker, Bergman, & Clough, 2010). Therefore, we are interested in how photo-taking affects people's memory of their experiences *without* revisiting photos.

Limited research on the effect of technology in general, and photography in particular, suggests photo-taking can diminish memory. Much like having access to the Internet reduces memory for factual information (Sparrow, Liu, & Wegner, 2011), having access to photos may reduce memory for one's experiences. That is, photographed content is committed less deeply to memory since one can "look it up later." Indeed, Henkel (2014) finds that taking photos reduced people's ability to recognize objects they had photographed, compared to objects they did not, presumably because they treated photos as external memory.

We offer a different perspective. We argue and empirically demonstrate that taking photos as part of an experience can in fact *boost* memory for visual content. This prediction rests on several important differences between prior investigations and the current research. Specifically, we argue that when people take photos of their experiences, it typically involves objectives and attentional processes that were not present in prior research. First, while people may happily take photos instead of remembering specific information (e.g., where they parked), experiences are central to the self (Howe & Courage, 1997) and are important in their own right. As a result, people often take photos of experiences in order to remember, not offload, what is captured in their photos. Second, previous work instructed participants which objects to photograph and which to merely examine (Henkel, 2014). While this approach provided control, it eliminated a distinct attentional process inherent to natural photo-taking: in order to decide *what* to photograph, people must search for aspects they may wish to capture. Consequently, volitional photo-taking requires attention to visual aspects of the experience, which should improve memory for visual content. Indeed, prior work using eye-tracking (Study 6; Diehl, Zauberman, & Barasch, 2016) shows that photo-taking increases visual attention to aspects of the experience likely to be photographed, as evidenced by longer and more frequent fixations. Hence, we suggest that when people take photographs volitionally, visual memory will be better than when they cannot take photographs (e.g., when not having a camera).

We also add to prior research by simultaneously investigating the effect of photo-taking on memory for non-visual, specifically auditory, aspects. We do so for several reasons. First, auditory and other non-visual sensory aspects are often integral to one's experiences. Second, while visual information is captured through photo-taking, non-visual information is not, and hence cannot be revisited. Third, examining the effect of photo-taking on memory for information not captured in photos provides a test of the underlying process.

If photo-taking directs greater attention to the experience in general, memory for all types of information should improve. We, however, predict an interaction of photo-taking and memory content: to the extent that attention is shifted towards visual aspects, photo-taking should improve visual memory, while not helping or even diminishing memory for auditory aspects.

> ***H1:*** *Volitional photo-taking (versus not having a camera) will heighten memory for visual but not auditory aspects of an experience.*

H1 compares memory between people who can take photos and those who do not have a camera. Another important comparison focuses on individuals with a camera, and contrasts visual memory for objects they photographed with memory for objects they did not photograph.

Extending the reasoning underlying H1, visual attention should be most strongly directed towards aspects people seriously consider and decide to photograph, compared to aspects that are not considered. Therefore, our attention-based mechanism predicts better visual memory for aspects that people volitionally photograph compared to those they do not.

> ***H2:*** *When people use a camera, visual memory for aspects that were photographed will be better than for aspects not photographed.*

We next present four studies comparing memory between those with and without a camera (H1). We then present a meta-analysis testing H2, comparing within-subject memory of photographed versus non-photographed aspects for participants who took photos. We also present additional between-subjects comparisons, contrasting memory of participants *without* a camera with memory of participants *with* a camera for (a) photographed aspects and (b) non-photographed aspects. These key analyses provide both control and a strong test of the effect of having a camera on visual memory.

Study 1

In this study, participants experienced an actual museum exhibit either with (*camera* condition) or without the ability to take photos (*no camera* condition). Those in the *camera* condition used their own devices and they themselves selected what to photograph, just as they would in real-life. Participants viewed the exhibit while listening to an audio guide, enabling us to test the predicted interaction of photo-taking and memory type.

Method

We recruited 297 participants (57.9% female; M_{age} = 20.4, SD = 2.1) who were paid $10. Sample size in this, and subsequent studies, was based on effect sizes from earlier studies we conducted, and the number of participants who completed each study over a given session. Participants started 20 minutes apart, ensuring they experienced the exhibit independently.

Participants first read detailed instructions (see Supplemental Materials) explaining that they would go on a self-guided tour of two museum exhibits: the focal exhibit featuring Etruscan artifacts and a second exhibit that served as a filler task. Participants also received a map of the two exhibits that outlined the order in which they should view them.

Participants were assigned to either the *no camera* or *camera* condition based on their time slot. The condition for the first hour was randomly determined and alternated each hour afterwards. In the *no camera* condition, participants left all belongings, including their cell phones, with a research assistant and were instructed to view the exhibits as they normally would. In the *camera* condition, participants also left their belongings behind, but kept their camera device. Participants were instructed to take pictures of anything they wanted during their visit, and told to take at least ten photos. Two participants who did not have their own devices were given cameras but were excluded from our analyses. Results do not change if their data are included.

All participants also received an audio guide providing information that could not be found within the exhibit. Participants could pause the guide, but had to listen to all tracks about eleven display cases in a specified order. Following the last track, the guide directed participants to view the second exhibit while listening to instrumental music, ensuring all participants viewed that exhibit for three minutes. One participant was excluded from our analyses due to an iPod malfunction.

After viewing both exhibits and returning to the sign-up desk, participants answered questions about visual and auditory information on a laptop. Importantly, participants were not informed about the memory test, preventing participants in the *camera* condition from taking photos in anticipation of being tested. We also eliminated any potential memory cues by collecting instruction sheets and audio guides, and by instructing participants in the *camera* condition to keep their devices out of view.

We created one visual and one auditory recognition question for each display case covered in the tour, excluding the first and last cases to avoid potential primacy or recency effects. All 18 memory questions used a forced-response format. For visual memory, participants identified which of three similar objects they had seen (see Figure 1). The two foils were objects from exhibits in the museum participants did not visit, and were similar in lighting and style to the target objects. For auditory memory, participants chose one of three answers to complete a factual statement mentioned in the audio guide. Participants first answered the nine auditory questions in random order, followed by the nine visual questions in random order. See Supplemental Materials for all memory questions for all studies.

Participants in both conditions took the same amount of time from starting their exhibit visit until completing the survey, which is the only timing data we collected (M_{camera} = 21.86 minutes, SD = 12.96 vs. $M_{no\ camera}$ = 20.29, SD = 10.44; $F(1, 290) = 1.31$, $p = .25$). Controlling for time spent does not alter our results (see Supplemental Materials).

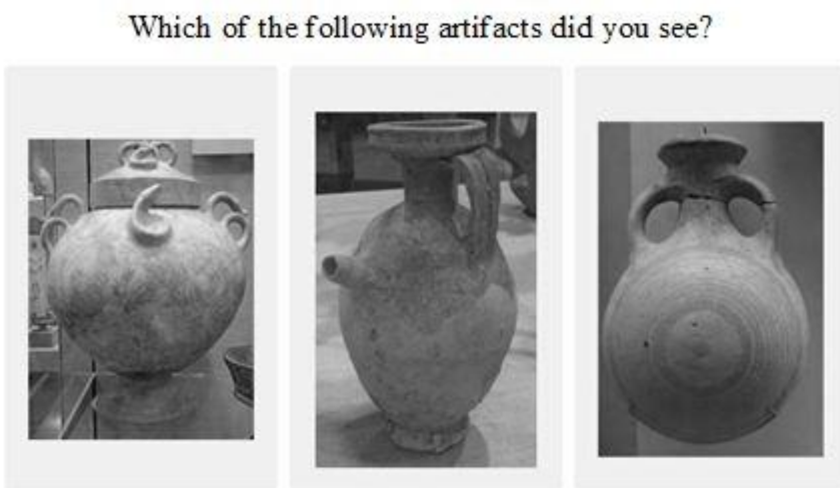


Figure 1. Example of a visual recognition question used in Study 1.

After completing the survey, participants in the *camera* condition were asked to email any photos they had taken to the experimenter (75.7% complied; $M_{photo\ number} = 6.4$, $SD = 2.5$). In the survey, participants in the *camera* condition self-reported having taken 7.1 photos on average. Note, 81.7% of participants took fewer than the requested ten photos. Our results hold, and if anything get stronger, when restricting the analysis to only those who fully complied with the instructions (see Supplemental Materials).

Results

Analyses are based on 294 participants, excluding three participants as described above. In all studies, we calculated the proportion of memory questions answered correctly for each memory type (visual and auditory) for each participant, which served as the primary dependent variables. Results from mixed ANOVAs (camera condition x memory type) appear in the main text; results from repeated measures binary logits appear in the Supplemental Materials. These analyses yield similar conclusions in this and all other studies.

Participants recognized more auditory ($M = 76.64\%$, $SD = 16.54$) than visual information ($M = 63.15\%$, $SD = 16.44$; $F(1, 292) = 108.01$, $p < .001$, $\eta_p^2 = .27$). There was no main effect of camera condition ($F(1, 292) = 2.15$, $p = .143$). Importantly, consistent with our key hypothesis, we found a significant camera condition by memory type interaction ($F(1, 292) = 12.79$, $p < .001$, $\eta_p^2 = .04$; see Figure 2). Participants in the *camera* condition recognized more visual information ($M = 66.51\%$, $SD = 15.98$) than participants in the *no camera* condition ($M = 59.83\%$, $SD = 16.27$; $F(1, 292) = 12.61$, $p < .001$, $\eta_p^2 = .04$). Further, participants in the *camera* condition recognized auditory information ($M = 75.34\%$, $SD = 17.68$) similar to participants in the *no camera* condition ($M = 77.93\%$, $SD = 15.28$; $F(1, 292) = 1.80$, $p = .181$).

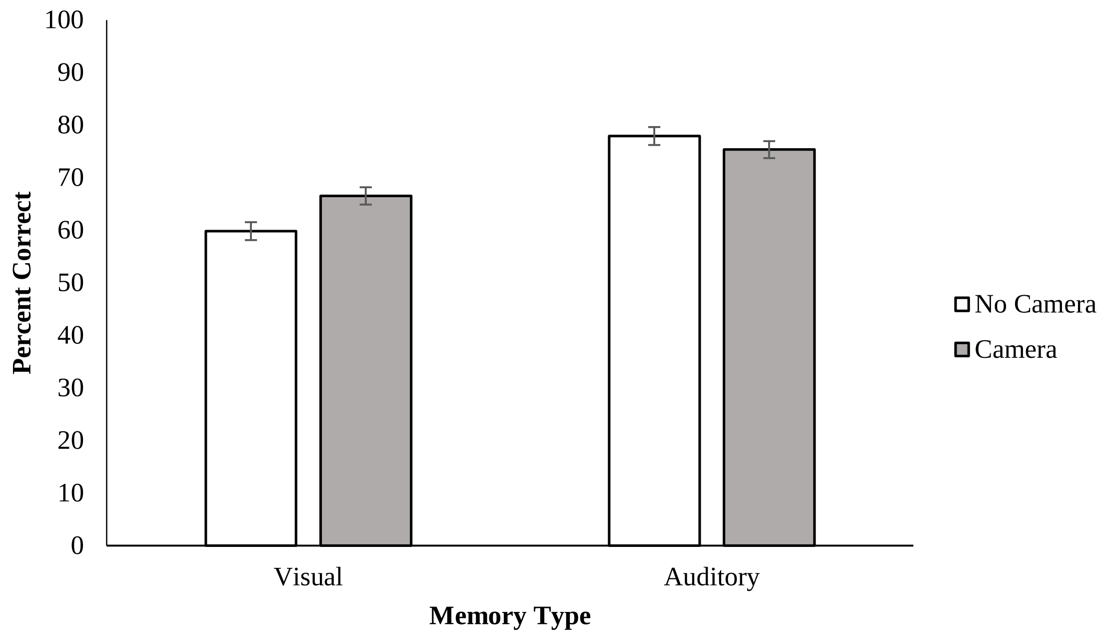


Figure 2. Visual and auditory memory performance for participants in the *no camera* and *camera* conditions in Study 1. Error bars represent ± 1 standard error.

Discussion

In a natural setting, we found that volitional photo-taking impacts visual and auditory memory differently. Participants who took photos remembered visual aspects of their experience *better* than participants who did not take photos, which was not the case for auditory aspects.

Notably, these visual memory results suggest that participants are not using photos as external memory (c.f., Henkel, 2014; Sparrow, Liu, & Wegner, 2011). This effect of photo-taking on visual memory cannot be explained by a lack of effort in the *no camera* condition, which would predict worse performance for both types of content.

While the decrease in auditory memory was not significant, this may be due to better memory overall for auditory aspects, leaving less room for the simple effect. Subsequent studies will address this calibration issue.

Study 2

In the remaining studies, we use a computer-based laboratory paradigm that mimics key features of first-person experiences. Doing so allows us to hold the experience constant across conditions, which isolates the effect of photo-taking on memory and tests the attention-based mechanism.

Method

We recruited 312 participants (47.5% female; M_{age} = 34.0, *SD* = 10.3) on Amazon's Mechanical Turk (MTurk) that were paid $1. MTurk participants in all studies were over 18 and U.S. residents.

This and subsequent studies used a unique computer interface in which participants experienced first-person perspective videos of different art gallery tours. All participants were told to imagine they were actually experiencing these tours in person. Participants were randomly assigned to simply experience the tours (*no camera* condition) or to take photos of the experience (*camera* condition). Participants in the *camera* condition could take photos by clicking an on-screen button (see Figure 3). Importantly, participants experienced the same tours for the same duration across conditions. Our software recorded the photos participants took, allowing us to identify which objects they photographed. Participants never saw any of these photos either during or after the experience. As in Study 1, the instructions framed this study to be about experiences, without mention of a memory test.

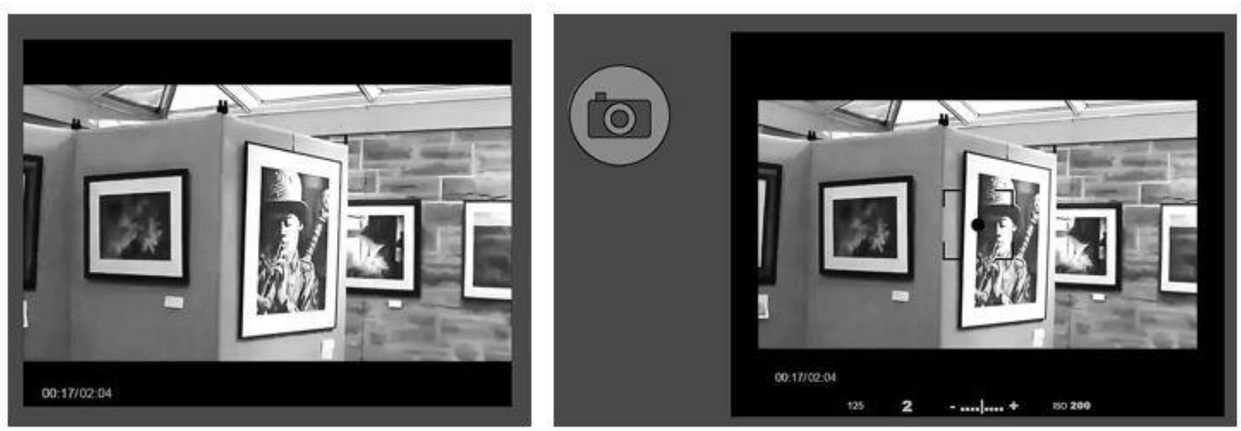


Figure 3. Computer interface for the *no camera* and *camera* conditions.

The focal experience for this and subsequent studies was a 90-second tour of a printmaking collection. Participants in the *camera* condition took an average of 8.1 photos during this experience. During the tour, participants heard a guide providing information about the prints. Participants also viewed two additional, similarly-narrated gallery tours of comparable length; one before and one after the focal experience. This allowed both familiarization with the interface and prevented primacy or recency effects. After experiencing all three galleries, participants read a short text as a filler task and were given an attention check. Participants who passed the attention check answered four questions about the text they had read. Fourteen participants (4.5%) failed the attention check and thus did not proceed and were not paid, leaving a final sample of 298. Participants were then asked seven visual and eight auditory memory questions, presented in random order. Questions were similar in format to Study 1.

Results

Participants recognized visual (*M* = 82.88%, *SD* = 21.92) better than auditory information (*M* = 52.89%, *SD* = 21.99, $F(1, 296) = 431.39$, $p < .001$, $\eta_p^2 = .59$). There was no main effect of camera condition ($F(1, 296) = 1.53$, $p = .217$). Importantly, as predicted, we find a significant camera condition by memory type interaction ($F(1, 296) = 48.89$, $p < .001$, $\eta_p^2 = .14$; see Figure 4). While participants in the *camera* condition recognized significantly more *visual* information (*M* = 89.33%, *SD* = 15.81) than participants in the *no camera* condition (*M* = 76.69%, *SD* = 25.03; $F(1, 296) = 26.93$, $p < .001$, $\eta_p^2 = .08$), they recognized significantly less *auditory* information (*M* = 48.97%, *SD* = 19.99) than those in the *no camera* condition (*M* = 56.66%, *SD* = 23.19; $F(1, 296) = 9.36$, $p = .002$, $\eta_p^2 = .03$).

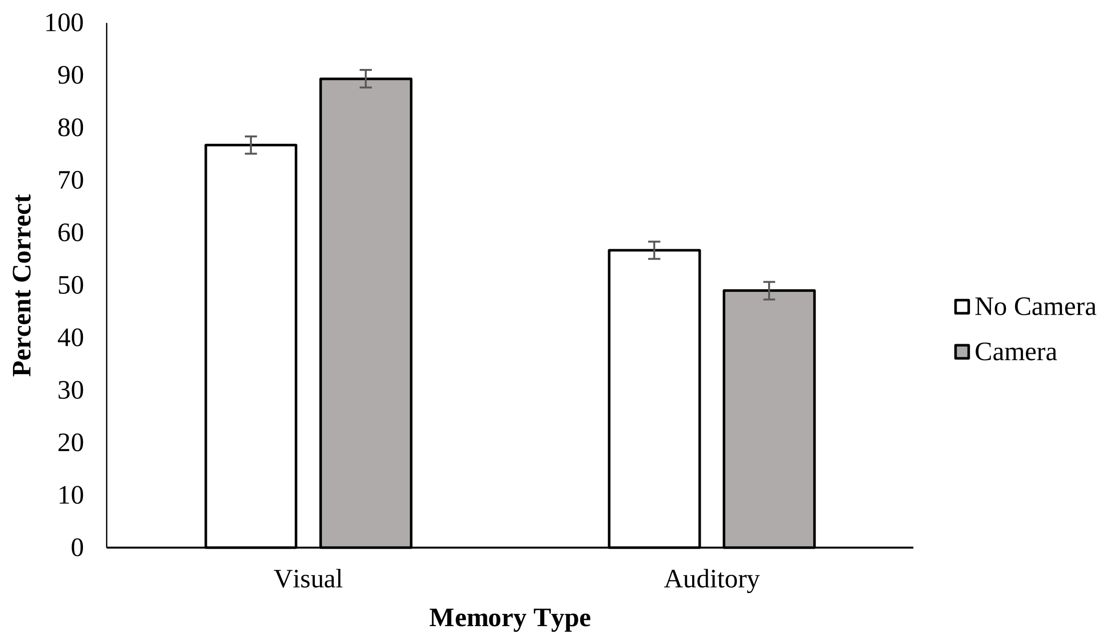


Figure 4. Visual and auditory memory performance for participants in the *no camera* and *camera* conditions in Study 2. Error bars represent ± 1 standard error.

Notably, the visual memory questions covered all artwork in the experience and were created a priori, without knowing what participants would photograph. Still, some objects are photographed more frequently while others are photographed less frequently, potentially because of many factors (e.g., they are more or less interesting, unique, etc.). In order to assess whether having a camera has an effect independent of any such factors, we analyze recognition for both the most and the least photographed objects.

When analyzing visual memory for only the three most-photographed objects, results replicate; participants in the *camera* condition recognized these objects significantly better (M = 92.69%, SD = 18.57) than participants in the *no camera* condition (M = 80.70%, SD = 30.09; $F(1, 296) = 16.98$, $p < .001$, $\eta_p^2 = .05$), indicating that photo-taking affects memory over and above any reasons that might have led people to photograph these objects more frequently. When analyzing visual memory for only the three least-photographed objects, results also replicate; participants in the *camera* condition recognized these objects significantly better (M = 90.18%, SD = 18.01) than participants in the *no camera* condition (M = 78.51%, SD = 28.30; $F(1, 296) = 17.89$, $p < .001$, $\eta_p^2 = .05$), indicating that the ability to take photo affects memory even for objects that are unlikely to be photographed. Results are robust across different specifications for this and all other studies (i.e., testing the 1, 2, and 3 most/least photographed items; see Supplemental Materials).

To address a possible concern that the narration in Studies 1 and 2 directs attention to objects highlighted by the guide, causing them to be remembered more, we conducted two additional studies using a different stimulus: a London bus tour without any narration (fully reported in the Supplemental Materials). Using multiple-choice recognition questions as before, participants in the *camera* condition had better visual memory than participants in the *no camera* condition (M_{camera} = 68.20%, *SD* = 18.82 vs. $M_{no\ camera}$ = 53.65%, *SD* = 21.38; $F(1, 296) = 38.71$, $p < .001$, $\eta_p^2 = .12$). Additionally, to assure results generalize to other memory measures, a second study used binary choice questions asking whether or not a given object had been seen (e.g., Jang, Wixted, & Huber, 2009). Again, participants in the *camera* condition recognized more than those in the *no camera* condition (M_{camera} = 80.12%, *SD* = 12.77 vs. $M_{no\ camera}$ = 70.00%, *SD* = 12.38; $F(1, 349) = 44.13$, $p < .001$, $\eta_p^2 = .11$).

Discussion

Supporting H1 and replicating Study 1, Study 2 demonstrates that taking photos during an experience affects memory of auditory and visual aspects differently. People who took photos during their experience remembered *more* visual aspects but, in this study, *fewer* auditory aspects than those who did not take photos. Jointly, our findings support the idea that across different contexts and measurement approaches, photo-taking directs attention towards visual aspects of the experience and away from other aspects, and that participants are not “offloading” memory of their experiences to their photos.

Study 3

We argue that when volitionally taking photos of experiences, people do not offload their memories, even when it is possible to do so (e.g., in Study 1, participants used their own devices and knew they could access their photos later). In Study 3, we further assess the robustness of this finding. Following previous work (Sparrow, Liu, & Wegner, 2011), we manipulate whether participants expect their photos will be saved versus deleted. In contrast to prior research, we expect our previous findings to hold, as people are unlikely to offload remembering their experiences even when that possibility is salient.

Method

We recruited 802 participants from MTurk (45.1% female; M_{age} = 33.9, *SD* = 10.8) in exchange for $1.20. Fifty-one participants (6.4%) who failed an attention check administered before the memory test did not proceed, leaving a final sample of 751 participants.

Participants were randomly assigned to one of three conditions. Participants in the *no camera* condition were simply told to experience the events. The two camera conditions differed only in the explanations of what would happen with participants' photos, which were closely modeled after Sparrow, Liu, and Wegner (2011). In the *photos saved* condition, participants were told that their photos would be saved, whereas in the *photos deleted* condition, participants were told that their photos would be deleted (see Supplemental Materials). The number of photos taken did not differ between camera conditions ($M_{photos\ saved}$ = 7.1, *SD* = 5.9 vs. $M_{photos\ deleted}$ = 7.5, *SD* = 4.9; $F(1, 507) = 0.65$, $p = .42$).

Results

Participants recognized more visual (*M* = 82.57%, *SD* = 20.69) than auditory information (*M* = 52.71%, *SD* = 22.11; $F(1, 748) = 973.81$, $p < .001$, $\eta_p^2 = .57$). There was no main effect of condition ($F(2, 748) = 0.63$, $p = .53$). Importantly, there was a significant condition by memory type interaction ($F(2, 748) = 20.87$, $p < .001$, $\eta_p^2 = .05$; see Figure 5).

For visual memory, planned contrasts show that participants in the *photos saved* condition recognized significantly more visual information (*M* = 84.22%, *SD* = 21.34) than participants in the *no camera* condition (*M* = 77.51%, *SD* = 21.37; $F(1, 748) = 13.23$, $p < .001$, $\eta_p^2 = .02$). Participants in the *photos deleted* condition also recognized significantly more visual information (*M* = 85.71%, *SD* = 18.50) than participants in the *no camera* condition ($F(1, 748) = 20.30$, $p < .001$, $\eta_p^2 = .03$). Further, visual recognition did not differ between camera conditions

($F(1, 748) = 0.68$, $p = .41$). Together, these results do not support the notion that people offload memory to photographs.

For auditory memory, planned contrasts showed that participants in the *photos saved* condition recognized significantly less auditory information ($M = 50.30\%$, $SD = 22.07$) than those in the *no camera* condition ($M = 56.56\%$, $SD = 22.75$; $F(1, 748) = 9.94$, $p = .002$, $\eta_p^2 = .01$). Participants in the *photos deleted* condition also recognized significantly less auditory information ($M = 51.44\%$, $SD = 21.12$) than the *no camera* condition ($F(1, 748) = 6.83$, $p = .009$, $\eta_p^2 = .01$). Auditory recognition did not differ between photo conditions ($F(1, 748) = 0.34$, $p = .56$).

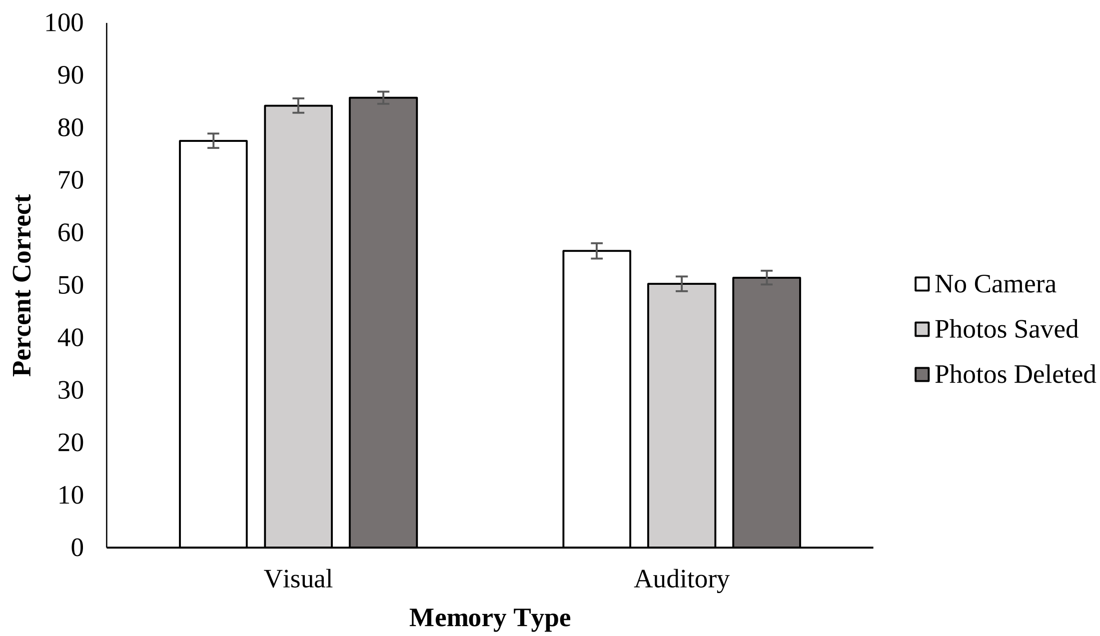


Figure 5. Visual and auditory memory performance for participants in the *no camera* condition and the two *camera* conditions (*photos saved* and *photos deleted*) in Study 3. Error bars represent ± 1 standard error.

Discussion

We again replicate the effect that photo-taking improves memory for visual aspects but reduces memory for auditory aspects of an experience. This is the case regardless of whether participants thought their photos would be saved or deleted. These findings provide additional support that people do not treat photos as external memory when photographing experiences, and that photo-taking shifts attention toward visual and away from other aspects.

Study 4

We argue that volitional photo-taking affects memory by shifting attention. Thus, it is not the physical act of taking photos that should affect memory, but rather how individuals approach the experience when taking photos. In Study 4, we examine whether merely *mentally* taking photos has similar memory effects.

Method

We recruited 372 participants from MTurk (51.3% female; M_{age} = 35.6, *SD* = 11.3) in exchange for $1.20. Twenty-three participants (6.2%) failed an attention check and did not answer any memory questions, resulting in a sample of 349.

Study 4 used the same gallery stimuli as before. In addition to the *camera* and *no camera* conditions, we added a *mental photo* condition in which participants were asked to mentally take a photo whenever they saw something they would photograph in real life. The computer interface was the same for the *no camera* and the *mental photo* conditions. After each tour, participants in the *mental photo* condition indicated how many mental photos they took, assessing whether they followed instructions. In the focal experience, participants in the *mental photo* condition reported taking 4.4 photos on average (*SD* = 2.7), while participants in the *camera* condition took 6.9 photos on average (*SD* = 5.1; $F(1, 222) = 21.52$, $p < .001$).

Results

Participants recognized more visual (*M* = 86.29%, *SD* = 18.37) than auditory information (*M* = 55.09%, *SD* = 20.13; $F(1, 346) = 617.27$, $p < .001$, $\eta_p^2 = .64$). There was no main effect of condition ($F(2, 346) = 0.79$, $p = .45$). Importantly, the condition by memory type interaction was significant ($F(2, 346) = 11.95$, $p < .001$, $\eta_p^2 = .06$; see Figure 6).

For visual memory, replicating previous findings, planned contrasts showed that participants in the *camera* condition recognized significantly more visual aspects (*M* = 90.27%, *SD* = 15.06) than participants in the *no camera* condition (*M* = 80.79%, *SD* = 21.64; $F(1, 346) = 16.11$, $p < .001$, $\eta_p^2 = .04$). Supporting the notion that the mental process rather than the mechanics of photo-taking heightens memory, participants in the *mental photo* condition (*M* = 88.03%, *SD* = 16.34) recognized significantly more visual aspects than participants in the *no camera* condition ($F(1, 346) = 9.58$, $p = .002$, $\eta_p^2 = .03$) and comparable visual memory to the *camera* condition ($F(1, 346) = 0.89$, $p = .35$).

For auditory memory, planned contrasts revealed that participants in the *camera* condition recognized significantly fewer auditory aspects (*M* = 52.54%, *SD* = 19.56) than those in the *no camera* condition (*M* = 57.77%, *SD* = 19.19; $F(1, 346) = 3.93$, $p = .048$, $\eta_p^2 = .01$). Auditory recognition for participants in the *mental photo* condition (*M* = 54.81%, *SD* = 21.39) was similar to the *no camera* condition ($F(1, 346) = 1.29$, $p = .26$). Auditory memory did not differ between the *mental photo* and *camera* conditions ($F(1, 346) = 0.73$, $p = .39$).

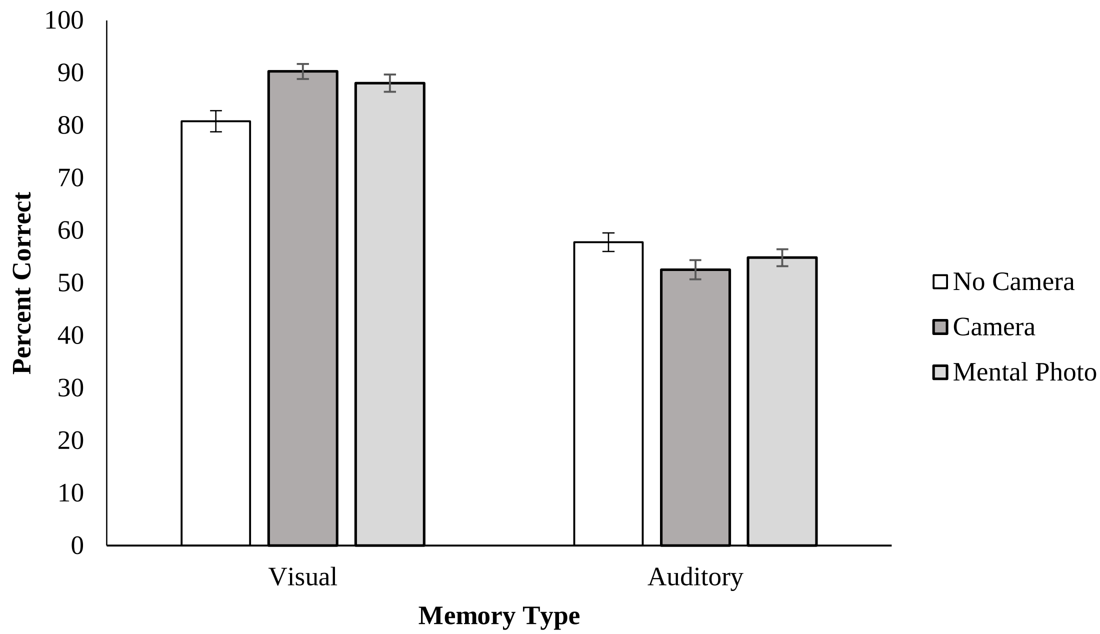


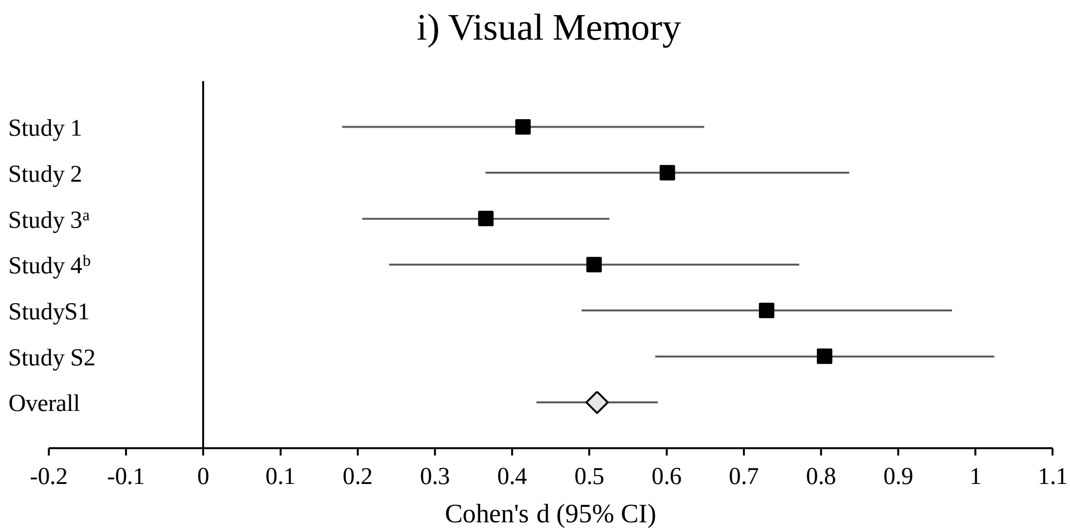
Figure 6. Visual and auditory memory performance for participants in the *no camera*, *camera*, and *mental photo* conditions in Study 4. Error bars represent ± 1 standard error.

Discussion

This study again replicates that taking photos of experiences increases memory for visual aspects while decreasing memory for auditory aspects. Further, simply taking photos *mentally* similarly heightens visual memory. These findings support the proposed attention-based process, and rule out that mechanical aspects, such as clicking a button, drive the effects.

Meta-Analysis

To examine the effect of having versus not having a camera on visual and auditory memory, we conducted a meta-analysis on all reported studies (methods from Lipsey & Wilson, 2001; fully reported in the Supplemental Materials). This analysis shows a reliable positive effect on visual memory (d = 0.54, 95% CI [0.45, 0.63]) and a smaller but reliable negative effect on auditory memory (d = 0.26, 95% CI [0.16, 0.36]). See Figures 7i and 7ii for a visual depiction of effect sizes across studies and overall.



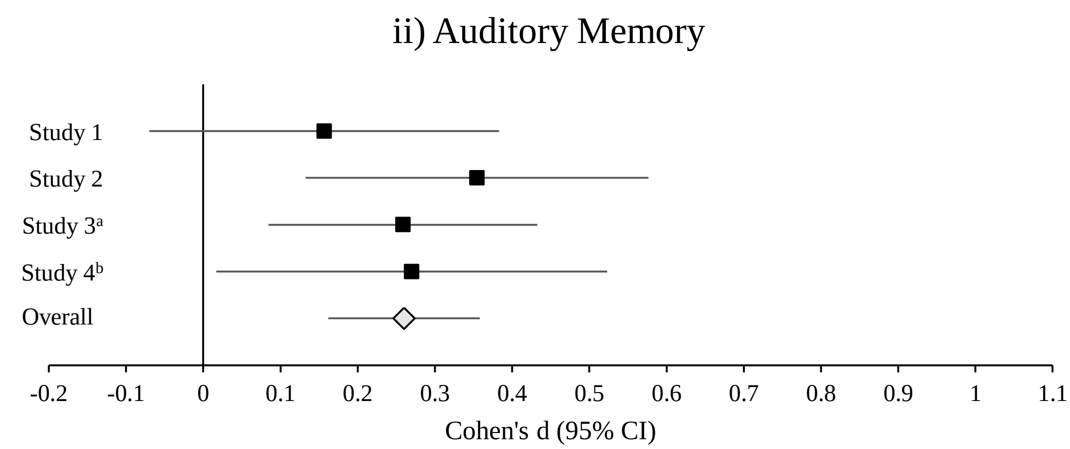


Figure 7. Forest plots of effect sizes across reported studies and overall weighted effect size for (i) visual memory and (ii) auditory memory.

a. The within-subject analysis combines both *camera* conditions (*photos saved* and *photos deleted*).

b. This analysis excludes the *mental photo* condition.

Probing Within-Subject Memory Differences

We next turn to examining how actually taking photos affects visual memory. We do so by conducting 1) a within-subject analysis for those in the *camera* condition, comparing visual memory for photographed versus non-photographed aspects (H2), and 2) a between-subjects analysis comparing visual memory in the *camera* condition for photographed and non-photographed aspects versus overall memory in the *no camera* condition.

Results

Table 1 presents results from both within- and between-subjects analyses for each study, as well as the combined weighted effect size across all reported studies. These results are based on ANOVAs; results from repeated measures binary logits of the same data appear in the Supplemental Materials and yield similar conclusions across all studies.

The within-subject analysis focuses only on the *camera* condition and compares memory for photographed versus non-photographed objects. As predicted, visual memory is significantly better for photographed aspects in all but one study. A meta-analysis of all reported studies shows that for those with a camera, having taken a photo (versus not) produced a small but consistent increase in visual memory (d = 0.33, 95% CI [0.27, 0.40]; fully reported in Supplemental Materials).

For the between-subject analyses, we compare visual memory in the *no camera* condition to both memory for photographed and memory for non-photographed aspects in the *camera* condition. Consistent with H1, we find that memory for *photographed* objects is significantly better in all studies compared to visual memory in the *no camera* condition; the combined weighted effect size across all reported studies is large and significant (d = 0.75, 95% CI [0.66, 0.84]). Furthermore, compared to memory in the *no camera* condition, even memory for *non-*

photographed objects is significantly better in half the studies, which across all reported studies produces a small but reliable effect (d = 0.26, 95% CI [0.17, 0.35]).

Study	% Correct Took photo (SD)	% Correct Did not take photo (SD)	**Within-subject Analysis** Took photo vs. Did not	% Correct No Camera (SD)	**Between-subjects Analyses** Took photo vs. No Camera	Did not take photo vs. No Camera
Study 1	86.06% (27.17)	76.01% (19.27)	$F(1, 92) = 8.42$ $p = .005$ $d = .31$	59.73% (16.27)	$F(1, 275) = 57.68$ $p < .001$ $d = 0.92$	$F(1, 292) = 46.35$ $p < .001$ $d = .80$
Study 2	91.40% (17.41)	80.37% (32.68)	$F(1, 78) = 12.69$ $p < .001$ $d = .33$	76.69% (25.03)	$F(1, 294) = 41.46$ $p < .001$ $d = .78$	$F(1, 231) = 0.23$ $p = .63$ $d = .07$
Study 3[a]	87.45% (21.89)	77.57% (35.62)	$F(1, 295) = 26.86$ $p < .001$ $d = .32$	77.51% (21.37)	$F(1, 737) = 40.45$ $p < .001$ $d = .47$	$F(1, 548) = 0.06$ $p = .80$ $d = -.02$
Study 4[b]	94.56% (14.71)	91.15% (21.96)	$F(1, 67) = 1.98$ $p = .164$ $d = .18$	80.79% (21.64)	$F(1, 225) = 20.41$ $p < .001$ $d = .60$	$F(1, 190) = 8.63$ $p = .004$ $d = .44$
Supplemental Study 1	71.31% (23.15)	64.78% (29.77)	$F(1, 152) = 5.29$ $p = .023$ $d = 0.20$	53.65% (21.38)	$F(1, 294) = 46.96$ $p < .001$ $d = .81$	$F(1, 279) = 11.74$ $p < .001$ $d = .41$
Supplemental Study 2	88.88% (16.28)	73.94% (26.25)	$F(1, 159) = 44.47$ $p < .001$ $d = 0.57$	69.61% (15.08)	$F(1, 343) = 134.45$ $p < .001$ $d = 1.25$	$F(1, 342) = 3.22$ $p = .074$ $d = .19$
Combined weighted effect size			$d = 0.33$ [0.27, 0.40]		$d = 0.75$ [0.66, 0.84]	$d = 0.26$ [0.17, 0.35]

Table 1. Within- and between-subject analyses of the effect of photo-taking on visual memory: Individual studies and meta-analyses

a. The within-subject analysis combines both *camera* conditions (*photos saved* and *photos deleted*).
b. This analysis excludes the *mental photo* condition.

Discussion

These analyses support H2 and further substantiate the proposed attention-driven process triggered by photo-taking. In line with photo-taking directing attention towards photographed aspects, participants had better memory for aspects they photographed, compared to aspects they did not photograph. Importantly, compared to those *without* a camera, participants with a camera had significantly better visual memory even for un-photographed aspects. This comparison serves as an important control and strong test of the positive effect of having a camera on visual memory.

General Discussion

In this paper, we study the effect of volitional photo-taking on memory for visual and auditory aspects of experiences. In certain situations, people may use photos to offload the responsibility of remembering specific details, which may reduce memory for such content. However, we argue that during self-relevant experiences, people in fact take photos in order to engage with and remember the experience. We demonstrate that, even without revisiting any photos, people who have a camera and intend to take photos, remember more visual but fewer auditory aspects. These effects are not limited to the physical act of taking photos; taking mental photos has similar effects. Additional analyses show that visual memory is strongest for photographed aspects, but those with a camera remember even non-photographed aspects better than those without camera. Meta-analyses across all reported studies further support these findings.

These results demonstrate a process where photo-taking improves visual memory by directing attention to photo-worthy aspects, in essence rendering visual content primary. In the contexts we studied visual aspects were naturally salient. In such contexts, photo-taking might in fact have a smaller effect than what one would expect in contexts where visual aspects are naturally less salient. Further, when attention is diverted from other aspects (i.e., making auditory content secondary), it reduces memory for those aspects. This process should not be unique to photo-taking; for example, when a technology focuses people's attention towards non-visual content, like when recording a sound clip, the same mechanism should improve auditory while reducing visual memory.

We examine the effect of photo-taking on memory without revisiting any photos and after a relatively short delay. The persistence of this effect is subject to future research. Further, in real-life, people take photos to revisit later, and this may affect, and even distort memory over time (e.g., Koustaal et. al, 1998). As we show, photographed aspects are remembered better to start with, and are also preserved in the photos. In contrast, non-photographed aspects are both remembered less initially and cannot be revisited through the photos, making these details even more likely to fade from memory over time.

These and other open questions suggest that many of the nuanced effects of photography on human behavior are yet to be well understood. Given the increasing centrality of photography in people's lives, addressing these open questions will be both theoretically interesting and relevant to people's lives.

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