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# Uninformative Photos Can Increase People's Perceived Knowledge of Complicated Processes

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To what extent can photos influence people's evaluations of their own knowledge? For example, can photos affect how well people think they understand processes? To answer this question, in six experiments we asked people to indicate how well they understood various processes (such as how rainbows form). Sometimes the processes that were described appeared after a related photo (such as a photo of a rainbow) whereas other times the processes appeared alone. People tended to report that they understood processes that appeared with photos better than processes that appeared alone. This pattern fits with the idea that photos make it easier to generate relevant thoughts and images—an experience people tend to interpret as evidence that they know or understand related information.

***General Audience Summary***

Do you understand how rainbows form? Would seeing a photo of a rainbow influence how you evaluated your knowledge? It seems obvious that such a photo would not influence you because it does not reveal the complex processes involved in rainbow formation. The photo should merely remind you of a phenomenon you have seen countless times. Yet when we asked people to evaluate their knowledge of several complicated processes, we found that seeing related, but uninformative, photos (a photo of a rainbow) led people to believe they knew more about the processes. We suspect that photos caused these effects by making it feel easier for people to bring related thoughts and images to mind—a feeling people might have taken as evidence they knew about the processes at hand. This finding has implications for education. When people are considering what they know about a scientific process, for example, uninformative photos might increase perceived knowledge and affect how much effort people put into learning related information.

*Keywords:* Photos, Cognitive fluency, Metacognition, Knowledge, Understanding

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How well do you know how rainbows form? Take a moment to rate your knowledge on a scale from 1, meaning you know nothing about that process, to 6, meaning you know everything about it. Assuming you played along, how did you go about assessing your knowledge of rainbow formation? Perhaps you attempted to retrieve related thoughts and images from memory, then determined whether those thoughts and images passed as knowledge of the process (Graesser & Hemphill, 1991). Now consider the image in Figure 1. Would viewing that photo change your assessment? The photo is, of course, uninformative in this situation. It does not reveal the physics of light refraction; instead, it merely reminds you of a phenomenon you have seen countless times. Nonetheless, in the following six experiments, we show that uninformative photos can encourage people to report that they know how complicated processes work.

One mechanism by which photos could affect judgments of knowledge is by providing semantic context, making related thoughts and images come to mind more easily (Collins & Loftus, 1975). And when information feels easy to bring to mind, people tend to interpret that feeling as evidence they are familiar with the information, that it is accurate or true, and that they know or understand it well (Alter & Oppenheimer, 2009; Jacoby, Kelley, & Dywan, 1989; Kelley & Lindsay, 1993; Rawson & Dunlosky, 2002; Whittlesea, 1993). This interpretation makes sense, considering the real-world association between the ease with which people process information and their familiarity with it: after all, having recently and/or frequently encountered something in the past does make it easier to bring it to mind in the present (Halberstadt, 2010; Jacoby & Dallas, 1981; Rawson & Dunlosky, 2002; Unkelbach, 2006).

This literature suggests, then, that photos could increase people's perceived knowledge of a process by enhancing the ease with which thoughts and images related to that process come to mind. Indeed, people sometimes make mistakes about why information feels easy to bring to mind, concluding that it is familiar or known when it really is not (Alter & Oppenheimer, 2009; Jacoby et al., 1989; Schwarz & Clore, 2007; Unkelbach & Greifeneder, 2013). In one study, people saw several lists of words and, after each list, decided whether they had seen a target word on the list. People thought they had seen target words (*boat*) more often when they appeared after highly related sentence fragments (*The stormy seas tossed the*. . .) compared to loosely related sentence fragments (*He saved up his money and bought a*. . .; Whittlesea, 1993; see also Lee & Labroo, 2004). That is, even though the semantic context provided no evidence that target words had actually been on the list, it biased people toward saying that words were old. Why? Presumably because, compared to the loosely related sentence fragments, the highly related sentence fragments made it surprisingly easy to bring target words to mind—a feeling people interpreted as evidence words were familiar (Dechene, Stahl, Hansen, & Wanke, 2009; Hansen, Dechene, & Wanke, 2008; Whittlesea & Williams, 1998, 2001a, 2001b).

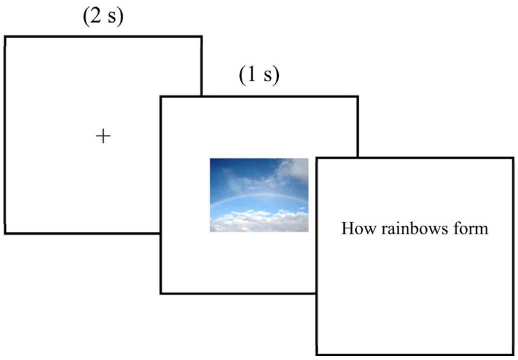

**Figure 1.** Example of how processes appeared with photos.

Recent work shows that photos can produce similar effects when they provide semantic context. In one study, people decided whether trivia claims (such as "Macadamia nuts are in the same evolutionary family as peaches") were true or false (Newman, Garry, Bernstein, Kantner, & Lindsay, 2012). Sometimes those claims appeared with related photos (a photo of macadamia nuts) and other times the claims appeared alone. Even though the photos were uninformative about the truth of the claims, they made people more likely to say claims were true. As with the highly related sentence fragments, photos might have made it feel easier to bring related thoughts and images to mind, an experience people interpreted as evidence of truth (see Alter & Oppenheimer, 2009; Reber & Schwarz, 1999; Unkelbach, 2007).

If photos can operate through such a mechanism, then their effects should extend to situations in which people evaluate their knowledge of complex processes, such as how rainbows form. After all, the feelings of ease that cause people to think words are familiar, or that claims are true, also cause people to believe they know or have learned information well. For example, in a series of experiments, people studied a list of words for a later recall test; some of the words appeared in a font that was large and easy to read, and other words appeared in a font that was small and more difficult to read. As people studied, they rated their confidence that they would be able to recall each word on a later test. People were more confident they would recall the easy words than the difficult words, but they actually recalled the two types of words at a similar rate (Rhodes & Castel, 2008; cf. Mueller, Dunlosky, Tauber, & Rhodes, 2014).

Similar effects arise when people judge their ability to recall words presented in crisp versus blurry font, to recall passages of text that are complete versus missing words, and to remember the meaning of Swahili words (such as "kelb") presented with a picture (of a dog) versus the English translation ("dog"; Carpenter & Olson, 2012; Rawson & Dunlosky, 2002; Yue, Castel, & Bjork, 2012). Put differently, people rely on feelings of ease as evidence that they know information well, even if those feelings are actually uninformative about their state of knowledge. So even though easily bringing the concept of rainbow to mind does not mean you know how they form, you may interpret that feeling of ease to mean that you do.

Taken together, these literatures suggest that uninformative photos should increase the extent to which people believe they know how complicated processes work. To examine that possibility, in six experiments we asked people to rate their knowledge of various processes. Before evaluating their knowledge, people either saw a photo that related to the process, or saw no photo.

In Experiments 1–5 we show that photos encouraged people to say they knew how processes work. Those experiments differed from each other in various ways, but because none of those differences caused different outcomes we report them together, noting methodological changes in Table 1. In Experiment 6, we provide evidence against the idea that photos encouraged people to say they know how processes worked because the photos actually produced a deeper understanding of the processes.

## Experiments 1–5

### Method

**Participants.** Across these experiments, we recruited participants from three sources: Amazon's Mechanical Turk, the University of Victoria's undergraduate psychology pool, and Victoria University of Wellington's undergraduate psychology pool.

**Design and procedure.** In all experiments, we used a within-subjects (Type of image: photo, no photo) design. We told participants their task was to rate their understanding of how several objects and processes worked (such as "How rainbows form"), either by responding on a scale from 1 (*I know nothing about how this process works*) to 6 (*I know everything about how this process works*), or by selecting "yes" or "no" as to whether they understood the process. In our early experiments, we explained what it meant to know "everything" about a process by showing participants an "expert description of how ballpoint pens work" (Rozenblit & Keil, 2002). In later experiments, we removed the reference to the expert description to avoid implying to participants that they would actually have to explain processes during the experiment (see Table 1 for more detail about the instructions and response options used in each experiment).

After explaining the judgment task, we told participants that sometimes they would see a photo before rating their understanding of each process, and other times they would see a gray box; then we gave examples of how each type of image would appear in the experiment proper. In Experiments 2–5 we also told participants that we would not ask them to provide any explanations about the processes, and that our interest was in their quick, intuitive, gut feeling as to the extent to which they did or did not understand a particular process. We included that instruction because if participants assumed they would need to explain the processes at some point, that could shift them toward evaluating information more analytically and make them less likely to rely on feelings of ease (see Halberstadt, 2010; Halberstadt & Catty, 2008).

Then the experiment proper began. Participants saw 90 descriptive phrases about natural and mechanical processes (such as "How rainbows form" and "How helicopters fly"). We developed these phrases by culling items from published research on people's understanding of processes (Rozenblit & Keil, 2002) and from websites dedicated to explaining how things work. We restricted our search to processes that involved familiar targets (such as rainbows and helicopters) to minimize the extent to which photos could actually help people understand processes (see Table A1 in the Appendix for the full list of critical items). To increase participants' engagement with the task, we included six filler items for which the process was relatively obvious (such as "How tweezers work").

For each descriptive phrase, participants first saw a fixation cross for 2 s, and then an image (either a photo, or a gray box) appeared for 1 s in the center of the screen. The boxes were of the same dimensions as the photos. Figure 1 shows how phrases appeared with photos. Photos always related to the process described, but did not depict the process. Immediately after the image disappeared, the phrase appeared on the screen in large black font against a white background, and participants made their response. In some experiments, we manipulated when participants could respond: participants responded at their own pace, after a delay of 5 s, or before a deadline of 3 s. We included these manipulations because people are more likely to rely on

**Table 1**
*Summary of Methodological Changes Across Experiments 1–5*

| Exp. | Participant pool (*N*) | % females | Response | Reference to expert description? | Told won't have to explain processes? | Response pace |
|---|---|---|---|---|---|---|
| 1 | MTurk (60); UVIC (44) | 66% | 1–6 | Yes | Not told | Self-paced |
| 2 | MTurk (67) | 45% | 1–6 | Yes | Not told | Self-paced |
| 3 | VUW (272) | – | 1–6 | No | Told | Self-paced vs deadline vs delay |
| 4 | MTurk (78) | 56% | Yes/No | No | Told | Self-paced |
| 5 | VUW (146) | 82% | Yes/No | No | Told | Deadline vs delay |

*Note*: In Exps 1–3, participants responded on a scale from 1 (*I know nothing about how this process works*) to 6 (*I know everything about how this process works*). If participants saw the ballpoint pen description, we used it to frame the rating task (we said: "If you understand how the process works well enough to write a passage like the one about ballpoint pens—not necessarily with the same words, but at a similar level of detail—you would select a 6. If you understand how the process works well enough to write some but not other parts of a passage like the one about ballpoint pens, you would select a number somewhere between 1 and 6 that best corresponds to your understanding. If you understand nothing about how the process works so that you could not write anything in a passage like the one about ballpoint pens you would select a 1"). If participants did not see the ballpoint pen description, we instead said "If you think you know everything about how the process works, you would select a 6. If you think you know nothing about how the process works, you would select a 1. If you think you know some aspects of how the process works but not all, you would select a number between 1 and 6 that best corresponds to what you know." In Exps 4–5, participants responded "Yes" or "No." We told them "If you think you understand how a process works, select the option that says 'Yes.' If you do not think you understand how a process works, select the option that says 'No.'" The delay instructions read "You will have to wait 5 seconds to rate your understanding of each process. After 5 seconds, the scale will appear on the screen and you will have as much time as you need to respond." The deadline instructions read "You will have 3 seconds to rate your understanding of each process. If you do not make your response within 3 seconds, the screen will disappear."

feelings of ease when they are under pressure or cognitive load (Greifeneder, Bless, & Pham, 2010).

Participants viewed the descriptive phrases in a random order, counterbalanced to appear after photos or boxes equally often. A third of the images were photos, two thirds were boxes. We chose this relatively low proportion of photos because the effects of ease tend to be largest when there are more difficult, relative to easy, items in a set (Westerman, 2008).

After the experimental phase ended, we asked Mechanical Turk participants questions to identify those who may have failed to comply with the experimental instructions. These participants read an article containing a secret word, and on the following page of the survey, we asked them to produce that word. Participants who produced the word passed the attention check (Oppenheimer, Meyvis, & Davidenko, 2009). We also asked Mechanical Turk participants whether they maximized their web browser, used their "back" or "refresh" button, completed the experiment in a single session, engaged in other tasks, spoke to others, worked in an environment free of noise and distraction and without help, or used a search engine to look the processes up. To encourage truthful responding, we told participants that regardless of their responses to these questions, we would fully compensate them for participating.

## Results and Discussion

Mechanical Turk participants who failed our attention check (23% across the experiments using that sample[1]) did not change the overall pattern of results. None of the participants reported having used a search engine to look the processes up, and excluding participants on the basis of their answers to our other questions (about whether they maximized their browsers, spoke to others, etc.) did not change the pattern of results. Therefore, we included all participants in the analyses to increase the precision of our estimated effect sizes. In Experiment 1, the Mechanical Turk and University of Victoria participant pools produced the same pattern of results, so we combined the two samples (reporting their effect sizes separately in the note under Table 2). Likewise, in Experiments 3 and 5, photos produced similar patterns whether participant responded at their own pace, after a delay, or before a deadline,[2] so we report the results collapsed across these groups.

We used the response latencies from Experiments 3 and 5 to estimate the extent to which photos made it easier for people to bring related information to mind. Subtracting the response latencies for processes that appeared with photos (Exp 3: $M = 5701$, $SD = 2010$; Exp 5: $M = 5653$, $SD = 2284$) from those that appeared alone (Exp 3: $M = 6006$, $SD = 2065$; Exp 5: $M = 5805$, $SD = 2251$) shows that photos speeded responses by an average of 305 ms (95% CI [257, 352], $t(271) = 12.59$, $p < .001$) in Experiment 3, and by 151 ms (95% CI [119, 184], $t(145) = 9.26$, $p < .001$) in Experiment 5. These findings fit with the idea that photos increased the ease with which participants considered the processes at hand.

We now turn to our primary question: to what extent did photos lead people to think they knew how processes worked? To answer this question, we calculated participants' mean knowledge ratings in Experiment 1–3, and the proportion of times participants responded "Yes" in Experiments 4–5. We then grouped those data according to whether processes appeared after photos or not and display the results in Figure 2. As the figure shows, photos nudged participants in the direction of reporting more knowledge. Indeed, calculating the raw effect sizes by subtracting the means of the no photo trials from those of the photo trials showed that in each experiment photos increased participants' perceived knowledge. Table 2 shows these raw effect sizes (ES) with their 95% confidence intervals (CI), along with standardized effect sizes (Cohen's *d*, calculated using the average *SD* of the photo and no photo means as the standardizer; see Cumming, 2012), and relevant null hypotheses statistical comparisons (*t* and *p* values).

To arrive at a more precise estimate of the size of these effects, we then conducted random effects model mini meta-analyses, in line with Cumming's (2012) recommendations. These mini meta-analyses derive an estimated effect size and its confidence interval based on each sample, with larger samples exerting more influence over the estimate. We carried out three of these meta-analyses. In the first two, we used raw effect sizes to estimate the

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[1] These failure rates are typical of those in research investigating Mechanical Turk as a participant pool, which range from 10 to 39% (Downs, Holbrook, Sheng, & Cranor, 2010; Goodman, Cryder, & Cheema, 2012; Kapelner & Chandler, 2010). We also suspect that these rates do not necessarily reflect poor participants, and are instead due to the type of attention check we used. The article came at the end of the experiment when participants would be most fatigued and tempted to skim or skip material (see Downs et al., 2010). Moreover, the effort involved in the reading task may be greater than that of evaluating one's knowledge. An attention check more similar to the main experimental task may have produced lower failure rates, and provided more reliable information for determining whether participants attended to that task. Note also that because the quality of data is not typically improved by excluding based on just one attention check, data from our participants who passed is not necessarily better than data of those who failed (Berinsky, Margolis, & Sances, 2014).

[2] In Experiment 3, there was an interaction between Type of Image and Response Pace, $F(2, 269) = 3.11$, $p = .05$. That is, the raw effect of photos was larger when participants responded before the deadline (0.24, 95% CI [0.13, 0.35], $t(94) = 4.45$, $p < .001$), compared to when they responded at their own pace (0.08, 95% CI [0.00, 0.16], $t(86) = 1.99$, $p = .05$), but not compared to when participants responded after the delay (0.14, 95% CI [0.06, 0.22], $t(89) = 3.40$, $p = .001$). But we report the results collapsed across Response Pace because the difference between the deadline and self-paced groups appeared to be unreliable, given that in Experiments 1 and 2 the estimated effect size for the self-paced participants was higher (.16 and .19) and more similar to the deadlined participants of Experiment 3. It is interesting that the photo effects for the deadlined participants were numerically larger than that of the delayed participants, in light of work showing that people are more inclined to draw on feelings of ease when they are under pressure or cognitive load (Greifeneder et al., 2010). But we place little weight on these patterns because they did not replicate in Experiment 5: there was no interaction between Type of Image and Response Pace, $F(1, 144) = 0.11$, $p = .74$, just a main effect of Type of Image, $F(1, 144) = 18.42$, $p < .001$. For the deadlined participants, photos produced a raw effect of 0.06, 95% CI [0.03, 0.09], $t(70) = 3.75$, $p < .001$; for the delayed participants, the raw effect was 0.07, 95% CI [0.02, 0.12], $t(74) = 2.77$, $p = .007$.

**Table 2**
*Effect Sizes for Experiments 1–5*

| Exp. | ES | *SD* | 95% CI |  | *N* | *t* | *p* | *d* | Sample |
|---|---|---|---|---|---|---|---|---|---|
|  |  |  | LL | UL |  |  |  |  |  |
| 1 | 0.16 | 0.34 | 0.10 | 0.23 | 104 | 4.93 | <.001 | .19 | MTurk; UVIC |
| 2 | 0.19 | 0.34 | 0.11 | 0.27 | 67 | 4.56 | <.001 | .26 | MTurk |
| 3 | 0.16 | 0.44 | 0.10 | 0.21 | 272 | 5.79 | <.001 | .24 | VUW |
| 4 | 0.07 | 0.20 | 0.02 | 0.11 | 78 | 3.07 | .003 | .30 | MTurk |
| 5 | 0.07 | 0.18 | 0.04 | 0.10 | 146 | 4.32 | <.001 | .36 | VUW |

*Note*: ES = effect size, the difference between photo and no photo means. LL and UL = lower and upper limits of the 95% CI of the ES. Standardized effect size (*d*) was calculated using the average of the photo and no photo standard deviations. For Exp 1, we also examined the effect sizes for the two samples separately. For MTurk, ES = 0.12, SD = 0.28, CI [0.05, 0.20], $t(59) = 3.45$, $p = .001$; for UVIC, ES = 0.22, *SD* = 0.40, CI [0.10, 0.34], $t(43) = 3.57$, $p < .001$.

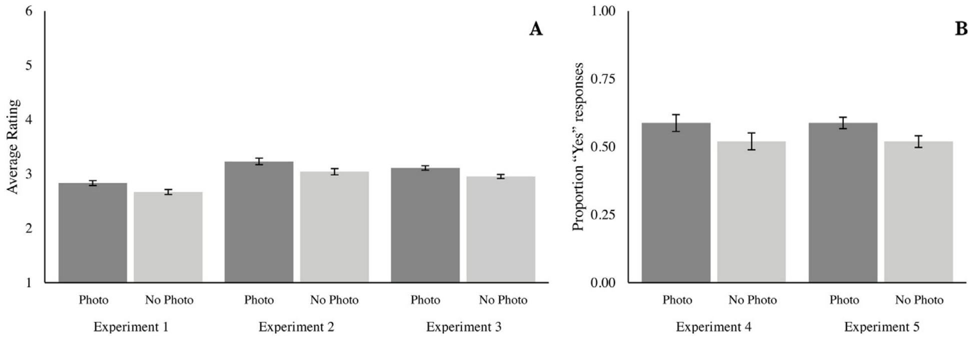

**Figure 2.** Participants' average ratings (panel A) and proportion of "Yes" responses (panel B) to items that appeared with or without photos. Error bars represent 95% within-subject confidence intervals for the Photo/No Photo effects (see Masson & Loftus, 2003).

difference between the photo and no photo means. We ran these analyses separately for Experiments 1–3 and Experiments 4–5 because those sets of studies used different dependent measures. The estimated effect size for Experiments 1–3 was 0.17, 95% CI [0.13, 0.20], $z = 8.84$, $p < .001$, and for Experiments 4–5 it was 0.07, 95% CI [0.04, 0.09], $z = 5.30$, $p < .001$. In the third meta-analysis, we included all experiments (and accounted for the different dependent measures by using the Cohen's *d* effect sizes reported in Table 2). The estimated effect size was 0.27, 95% CI [0.21, 0.34], $z = 8.51$, $p < .001$.

In each experiment, photos increased participants' perceived knowledge of complicated processes. But a critic might note that our effect sizes are small, and wonder what that suggests about the consistency of these photo effects. Although it is possible photos increased people's perceived knowledge to a small degree reliably, it is also possible they did so to a large degree for only a small set of processes—perhaps those that were generally less well known, and which photos could actually provide useful information about.

To depict the consistency of these photo effects, we combined the data from Experiments 1–3, calculated the average rating each item received when it appeared with a photo versus alone, then plotted the photo ratings against the no photo ratings. We display the results in Figure 3, which shows that most items lay above the diagonal, suggesting photos increased people's perceived knowledge for most of the processes. More to the point, the figure also suggests the results were driven not by a few items producing large increases in perceived understanding, but by the majority of items producing small increases.[3] In other words, it is unlikely that our effects arose due to a few items that depicted useful information for understanding the processes.

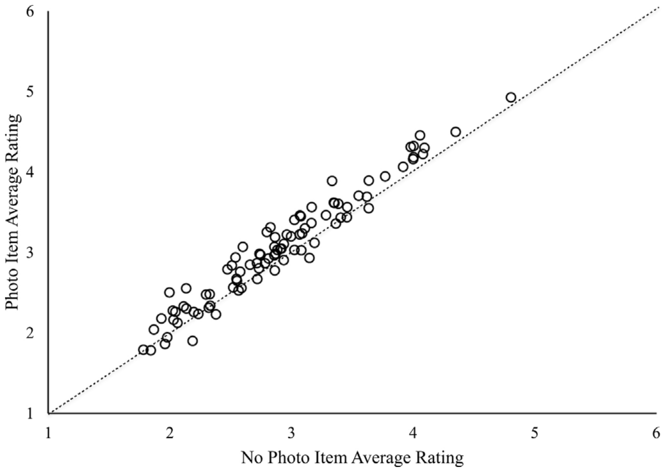

**Figure 3.** Relationship between the photo and no photo average ratings for each item (across Experiments 1–3). The diagonal shows what would be a perfect correlation.

Of course, it is still possible that the majority of photos provided some details that participants would not otherwise

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[3] This conclusion also holds when we account for the variability across items by using a mixed effects model.

have thought up themselves, thereby increasing perceived understanding by increasing the depth with which participants represented processes (accurate or not). Such a mechanism does not require people to draw on the ease with which those thoughts and images come to mind. Therefore, we attempted to replicate our findings in Experiment 6—but by using only photos we could empirically demonstrate to be unlikely to increase the depth with which people represented processes.

## Experiment 6

### Method

We determined which photos were likely to increase the depth of people's representations using two steps. In step one, we (authors BAC and KF) classified each photo as either "potentially helpful" or "not at all helpful"; after removing the photos classified by either author as "potentially helpful" 43 items remained. In step two, we confirmed these classifications by showing the "not at all helpful" photos to a new group of 100 Mechanical Turk participants and asking them to explain how each process worked in as much detail as possible. We created two sets of 20 items (removing three of the 43 items at random to create these even sets) and showed each participant one of those sets. Items appeared one at a time on the computer screen, and participants typed their explanation into a text box. Half the items showed photos along with the descriptive phrases, and half the items showed descriptive phrases alone.

Then a research assistant (blind to the photos manipulation) rated these explanations according to a seven-point scale used in previous research. The scale anchors and midpoint use text along with diagrams to give examples of what would be low, mid, and high level explanations for how a crossbow works; on the scale, a rating of 1 represents the lowest level of understanding and 7 the highest (Rozenblit & Keil, 2002). We told the RA to make her ratings based not on the accuracy of participants' explanations (which would require her to have a sophisticated understanding of the 40 processes), but instead based on the depth of those explanations. To check the reliability of this rating procedure, the first author also rated 20% of the explanations; those ratings correlated with the RA's, $r = .85$, 95% CI [.82, .88]. Fifteen participants had either reported using a search engine to look the processes up, or were caught doing so when a research assistant coded their explanations (if the exact explanation appeared more than once—word for word—it was typically one of the first explanations that came up in a Google search). We removed these participants from the analyses.

Did these photos increase the depth of the explanations participants provided? Our evidence suggests the answer is no: the ratings for items that appeared with photos were similar to those of items that appeared without photos, a raw effect of 0.02, 95% CI [−0.10, 0.14], $t(84) = 0.37$, $p = .71$. We found converging evidence when we ran a Bayesian analysis of these data (with JASP) using the estimated effect size from our meta-analysis ($z = 0.27$) as the prior. The Bayes factor was 4.50:1 in favor of the null. Together, these findings imply that these particular photos do not deepen people's explanations of processes.

Finally, in our primary experiment using a new group of Mechanical Turk participants we replicated the patterns from Experiments 1–5, but by drawing only from the new set of items. In other words, we examined whether the photo effect would emerge even when the photos were unlikely to increase participants' depth of understanding. Of the forty items, we removed the four for which photos had most increased depth of understanding to further reduce the plausibility of that mechanism, and so that we could split the item set into even thirds for counterbalancing. Along with these 36 critical items, we included three filler items. Because we reduced our item set by more than half, we increased our sample size; we aimed for 250 Mechanical Turk participants, and ultimately recruited 256. Aside from those changes, the design and procedure of this experiment were the same as in Experiment 3.

### Results and Discussion

Ten percent of the participants failed the attention check, but (as in Experiments 1–5) those participants did not change the overall pattern of results so we included them in the analysis. More to the point, we found evidence at odds with the idea that the results of Experiments 1–5 arose solely because photos provide information that increase the depth of people's knowledge. In this experiment, we used photos that were demonstrably unlikely to deepen people's knowledge, yet photos still led participants to rate their knowledge as higher; indeed, photos produced a raw effect size of 0.11 [0.04, 0.17], $t(255) = 3.16$, $p = .002$, $d = 0.12$. Note that although this effect size is numerically smaller than those of Experiments 1–3 (which used the same scale, and range from 0.16 to 0.19), the confidence intervals across those studies largely overlap, suggesting the effects are similar.

## General Discussion

Across six experiments, people's ratings of how well they knew how processes worked were higher for processes presented with photos than for processes presented without photos. This finding fits with the idea that by providing semantic context, photos make it feel easier to bring concepts to mind—a feeling people tend to interpret as evidence they know or understand related information (Alter & Oppenheimer, 2009; Kelley & Lindsay, 1993; Rawson & Dunlosky, 2002; Rhodes & Castel, 2008; Whittlesea, 1993; Yue et al., 2012).

What is intriguing, and worrying, about these findings is that photos increased the extent to which people claimed to know information that went well beyond what was in the photo; for example, they did not just claim to know what rainbows were, but to know the processes that produce rainbows. These results have implications for education. We know that pairing scientific texts (for example, texts describing how lightning forms) with uninformative images (a photo of lightning) tends to harm people's comprehension for the text (Carney & Levin, 2002; Mayer & Gallini, 1990; Sanchez & Wiley, 2006; Serra & Dunlosky, 2010). Why? In the literature, there have been two primary explanations. One explanation is that uninformative images distract people, drawing their attention away from the more relevant information in the text (see Sanchez & Wiley, 2006). Another is that because people believe photos help learning, seeing a photo leads people to overestimate how well they have encoded the information (Serra & Dunlosky, 2010). Our findings suggest that a third mechanism may contribute: that uninformative photos lead people to think they understand how processes work, discouraging people from exerting the effort needed to comprehend the text (for similar ideas, see Ackerman & Leiser, 2014; Jaeger & Wiley, 2014; Kornell & Bjork, 2007). Whether photos actually wield their effects in study situations is a question worthy of future research—given that fluency is often overwritten when people have more relevant information to draw on, such as details in a passage of text (Unkelbach, 2007), or when competing against sources of disfluency (attempts to explain processes; Halberstadt & Catty, 2008; Rozenblit & Keil, 2002).

On the theoretical side, our findings mesh well with the literature showing that when information feels easy to process, people take that feeling to mean they will remember the information well (Carpenter & Olson, 2012; Rawson & Dunlosky, 2002; Yue et al., 2012). Analogously, our photos might have made related thoughts and images come to mind more easily—a feeling people took as evidence they knew how the processes worked. Such a mechanism suggests that unrelated photos might do the opposite: tempering people's judgments about their knowledge and decreasing people's confidence about what they know. After all, it should be more difficult for people to bring ideas about rainbows to mind if they view a photo (of, say, a chair) that activates unrelated concepts. And so people might interpret that feeling of difficulty as evidence that their understanding of rainbows is inaccurate or sparse (Kelley & Lindsay, 1993; Reber & Schwarz, 1999; Song & Schwarz, 2008; Unkelbach, 2007; for a review, see Alter & Oppenheimer, 2009). Recent work supports that possibility. When trivia claims appear with unrelated photos (say, a claim about macadamia nuts paired with a photo of a trash can), they lead people to believe those claims are false (Newman et al., 2015). Whether unrelated photos decrease perceived knowledge is a worthy area of research, given that shaking people's confidence in their knowledge tends to encourage people to adopt the more effortful, analytical processing strategies that boost comprehension (Alter, Oppenheimer, Epley, & Eyre, 2007; Diemand-Yauman, Oppenheimer, & Vaughan, 2011; Song & Schwarz, 2008).

But there are other mechanisms that may explain—or contribute to—our effects. For example: might people's beliefs about how photos boost knowledge play a role? If people associate photos with gaining knowledge (e.g. Serra & Dunlosky, 2010), that belief could itself increase their tendency to say they know more about processes that appear with photos—a mechanism that does not require feelings of ease (for similar ideas, see Mueller et al., 2014). Or perhaps photos worked in part by hiding the complexity of the processes; after all, our photos depicted the result of the process, rather than the more complex causal relations between components, and so they might have led people to represent processes in a simple, schematic way. And encouraging people to adopt simplified representations of events and processes makes people more confident they understand them (Alter, Oppenheimer, & Zemla, 2010; Namkoong & Henderson, 2013; see also, Rozenblit & Keil, 2002). Of course, feelings of ease could also initiate a similar process—signaling to people that their knowledge is complete, and so there is no need for them to try to access the details (Alter et al., 2010; Rozenblit & Keil, 2002; Vallacher & Wegner, 1987). Another question worthy of future research, then, is how these factors combine to keep people from realizing just how little they know.

## Conflict of Interest Statement

The authors declare no conflict of interest.

## Author Contributions

BAC, DSL, MG, and KF conceived and designed the experiments. BAC and KF performed the experiments. BAC, KF, and MG analyzed and interpreted the data. MG contributed analysis tools. BAC, DSL, and MG wrote the paper and KF provided commentary. All authors approved the final version of the manuscript for submission.

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## Appendix A.

**Table A1**
*List of Critical Items Used in the Experiments*

| Item |
|---|
| How nuclear reactors produce electricity |
| How floods happen |
| How radios work |
| How rainbows form |
| How flowers reproduce |
| How ants form hills |
| How LCD screens work |
| How watches work |
| How cellular phones work |
| How cocoons are made |
| How tsunamis form |
| How water turns to ice |
| How craters form |
| How batteries store electricity |
| How VCRs work |
| How bees make honey |
| How wasps build nests |
| How fog forms |
| How full moons happen |
| How fossils form |
| How comets form |
| How coral reefs form |
| How hearing aids work |
| How water faucets control water flow |
| How mountains form |
| How beavers build dams |
| How crickets chirp |
| How hot springs form |
| How tears form |
| How snakes shed their skin |
| How silkworms make silk |
| How icicles form |
| How dear antlers form |
| How clouds form |
| How volcanoes erupt |
| How ears hear |
| How glasses work |
| How wrinkles form |
| How rock layers form |
| How shooting stars happen |
| How earthquakes happen |
| How noses smell |
| How bones grow |
| How snowflakes form |
| How rivers form |
| How scanners capture images |
| How quicksand forms |
| How incinerators work |
| How fireflies glow |
| How eyes see |
| How cameras make images |
| How plants grow |
| How diamonds form |
| How seashells form |

**Table A1** (*Continued*)

| | |
|---|---|
| How pearls form | How birds build nests |
| How ants carry more than their weight | How a computer mouse works |
| How car ignition systems start engines | How canyons form |
| How car gearshifts work | How tornados form |
| How spiders build webs | How crystals form |
| How sand is made | How tongues taste |
| How lightning strikes | How glaciers form |
| How whirlpools form | How smoke detectors work |
| How telephone wires transmit sound | How tree sap forms |
| How lava forms | How deadbolt locks open with keys |
| How microphones work | How chameleons change color |
| How helicopters fly | How bathroom scales work |
| How brains coordinate behavior | How fluorescent lights work |
| How rain forms | How feathers help birds fly |
| How caves form | How freckles form |
| How coal forms | How lizards grow new tails |
| How speedometers work | How jet engines work |
| How ocean waves form | How scuba-gear regulates air pressure |

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