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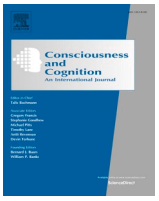

Typicality modulates the visual awareness of objects

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ABSTRACT

In the present study, we assessed whether typicality can influence the visual awareness of objects. Participants tracked moving images of objects and counted how often members of one category bounced off the edges of the display. On the last trial, an unexpected object moved across the display. In our first two experiments, this object could belong to the same category as the tracked or untracked objects. While participants were more likely to notice atypical members of the untracked category, this pattern of results reversed when participants tracked atypical objects. In our last two experiments, the unexpected object could belong to the same category as the tracked objects or a new category of objects. In this case, participants were more likely to notice typical members of both the tracked category and the new category. Together, these findings suggest that typicality can modulate the visual awareness of objects.

1. Introduction

Attention plays an important role in our visual awareness of the world. For example, as research on inattentional blindness (Mack & Rock, 1998; Simons & Chabris, 1999), change blindness (Rensink, O'Regan, & Clark, 1997; Simons & Levin, 1997), and the attentional blink (Dux & Marois, 2009; Raymond, Shapiro, & Arnell, 1992) demonstrate, we often fail to notice salient or unexpected objects when our attention is engaged in another task. Why do we often fail to notice these objects, even when they are known to capture attention? According to many theories, although attending to an object does not always guarantee awareness of that object, some degree of attention is necessary for objects to enter awareness (e.g., Cohen, Cavanagh, Chun, & Nakayama, 2012). Consistent with this suggestion, many factors that are known to influence attention have also been shown to influence visual awareness. For example, both bottom-up factors, such as visual salience (Most, Clifford, Scholl, & Simons, 2005), and top-down factors, such as observers' task goals (Drew & Stothart, 2016; Most et al., 2005; Most et al., 2001), have been found to modulate the visual awareness of objects.

One factor that strongly influences visual awareness is observers' *attentional set,* or the set of features that observers use to guide attention (e.g., Folk, Remington, & Johnston, 1992). For example, when observers adopt an attentional set for a particular color, they are more likely to notice objects that share this color (Drew & Stothart, 2016; Most et al., 2005; Most et al., 2001; see also Simons & Chabris, 1999). However, in addition to adopting attentional sets for relatively simple features, such as color, observers can also adopt attentional sets for a particular semantic category, such as food or furniture (Nako, Wu, Smith, & Eimer, 2014; Wu et al., 2013; Wyble, Folk, & Potter, 2013; Yang & Zelinsky, 2009). To test whether these categorical attentional sets can influence visual awareness, Clement, Stothart, Drew, and Brockmole (2019) had participants track moving images of objects (e.g., monkeys and rabbits) and count how often members of one category bounced off the edges of the display. On the last trial, an unexpected image of a monkey or rabbit

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Table 1
Exclusion criteria and number of participants excluded from each experiment.

Exclusion Rule	Exp. 1	Exp. 2	Exp. 3	Exp. 4
Already participated in the present experiment	6 (0.90%)	8 (1.01%)	11 (1.39%)	8 (1.05%)
Did not have the correct browser resolution	3 (0.45%)	1 (0.13%)	2 (0.25%)	1 (0.13%)
Reported not having normal or corrected-to-normal vision	36 (5.38%)	42 (5.28%)	41 (5.19%)	38 (4.98%)
Failed a colorblindness test	26 (3.89%)	33 (4.15%)	32 (4.05%)	32 (4.19%)
Failed to pay attention to the instructions	91 (13.6%)	130 (16.3%)	101 (12.8%)	92 (12.1%)
Entered a nonsensical open response or reported that the task did not work correctly	64 (9.57%)	100 (12.6%)	99 (12.5%)	77 (10.1%)
Reported being familiar with the inattentional blindness task	177 (26.5%)	305 (38.3%)	311 (39.4%)	296 (38.8%)
Total excluded	269 (40.2%)	396 (49.7%)	390 (49.4%)	363 (47.6%)

Note. Participants could be excluded for multiple reasons.

moved across the display. Critically, participants were more likely to notice this object when it belonged to the same category as the tracked objects (see also Koivisto & Revonsuo, 2007; Most, 2013). Thus, when observers adopt a categorical attentional set, members of this category are more likely to enter awareness.

While the previous findings suggest that categorical attentional sets can influence visual awareness, not all objects are equally representative of a category. Instead, some objects are more typical members of a category than others. While typicality is known to influence processes such as categorization and object recognition (e.g., Murphy & Brownell, 1985; Rosch, 1975; Rosch & Mervis, 1975), relatively few studies have examined the effects of typicality on attention. Moreover, while some studies have found that typicality can facilitate search for categorical targets (Maxfield, Stalder, & Zelinsky, 2014; Robbins & Hout, 2020), other studies have only observed effects of typicality on target identification (Castelhano, Pollatsek, & Cave, 2008). To resolve these conflicting findings, Lim, Clement, and Pratt (2021) had participants search for a target category of objects in a rapid stream of images. On each trial, a flanker image appeared above or below the central stream. Participants were less accurate at detecting the target when the flanker belonged to the same category as the target, suggesting that members of this category captured attention (see also Wyble et al., 2013). Moreover, they were even less accurate when the flanker was a typical member of this category. Together, these findings suggest that when observers adopt a categorical attentional set, attention is biased toward typical members of this category.

Overall, the previous findings suggest that typicality can influence the guidance of attention. Because attention plays an important role in our visual awareness of the world, it is possible that typicality may also influence the visual awareness of objects. Such an outcome would not only provide converging evidence for the effects of typicality on attention, but would also suggest that typicality plays an important role in the visual awareness of objects. To test whether this is the case, we conducted four experiments using an inattentional blindness task. Participants tracked moving images of objects (e.g., chairs and clocks) and counted how often members of one category bounced off the edges of the display. On the last trial, an unexpected object moved across the display. Previous evidence suggests that participants should be more likely to notice objects that belong to the same category as their current attentional set (Clement et al., 2019; Koivisto & Revonsuo, 2007; Most, 2013). Moreover, if typicality influences visual awareness, participants should be even more likely to notice typical members of this category.

2. Experiment 1

In Experiment 1, we assessed whether typicality modulates the visual awareness of objects. Participants tracked moving images of objects and counted how often members of one category bounced off the edges of the display. On the last trial, an unexpected object moved across the display. This object could belong to the same category as the tracked or untracked objects, and could be a typical or atypical exemplar of this category. If categorical attentional sets influence visual awareness, participants should be more likely to notice this object when it belongs to the same category as the tracked objects (Clement et al., 2019; Koivisto & Revonsuo, 2007; Most, 2013). Moreover, if typicality influences visual awareness, participants should be even more likely to notice this object when it is a typical exemplar of this category.

2.1. Methods

2.1.1. Participants

Assuming a small effect size ($OR = 2.0$), a moderate probability of noticing the unexpected object under the null hypothesis ($p_0 = 0.5$), and no shared variance between our independent variables ($R^2 = 0$), an a priori power analysis conducted using G*Power 3 (Faul, Erdfelder, Lang, & Buchner, 2007) indicated that a sample size of 374 participants would be sufficient to detect a two-way interaction between unexpected object category and unexpected object typicality at 80% statistical power. As a result, a group of 669 participants

Table 2
Number of participants assigned to each experimental condition in Experiments 1 and 2.

	Exp. 1		Exp. 2	
Unexpected Object Category	Typical	Atypical	Typical	Atypical
Tracked	96 (24.0%)	102 (25.5%)	104 (26.3%)	95 (23.8%)
Untracked	100 (25.0%)	102 (25.5%)	103 (25.8%)	98 (24.3%)

Note. Participants who were excluded from analysis are not reported here.

Fig. 1. Example images from each object category in the present study. Typical exemplars are presented on the left side of each pair, and atypical exemplars are presented on the right.

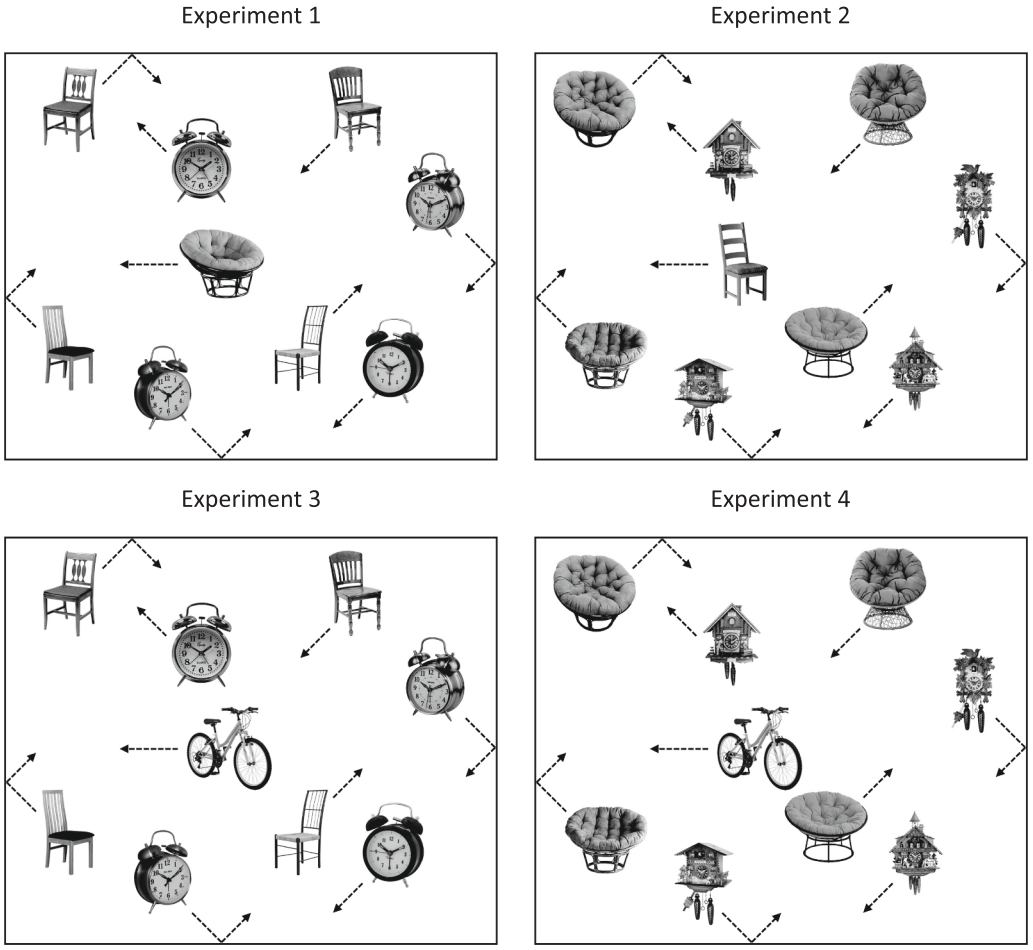

Fig. 2. The inattentional blindness task used in the present study. The horizontally moving object represents the unexpected object, which only appeared on the last trial.

were recruited and tested online using Amazon Mechanical Turk; however, 269 participants were excluded for one or more of the reasons listed in Table 1. The remaining 400 participants (143 females; mean age = 37.4 years) were randomly assigned to one of four experimental conditions (see Table 2). All participants received $1.25 for participating in the experiment.

2.1.2. Apparatus and stimuli

Stimuli were adapted from Lim et al. (2021), and consisted of 480 images of objects. The images were presented in grayscale and were equated in luminance using the SHINE Toolbox (Willenbockel et al., 2010). Each image belonged to one of 24 object categories, and was a typical or atypical exemplar of its category (see Fig. 1). Typical exemplars were common, everyday objects that were representative members of their category, while atypical exemplars were uncommon or otherwise unrepresentative members of their category. Each object category consisted of 10 typical exemplars and 10 atypical exemplars. In a previous study, a group of 100 participants rated how typical the objects were of their category using a 7-point Likert scale (Lim et al., 2021). Critically, participants rated typical exemplars ($M = 6.17$, $SD = 0.79$) as significantly more typical than atypical exemplars ($M = 4.22$, $SD = 1.11$), $t\,(99) = 15.69$, $p < .001$, $\eta_p^2 = 0.713$. Average typicality ratings for each category are presented in the Appendix. All images subtended 128 × 128 pixels, and were presented on a 546 × 666-pixel white background. Participants viewed the images on their own computers. To ensure that participants could properly complete the task, all participants had a browser resolution of at least 546 × 666 pixels.

2.1.3. Procedure

At the beginning of each trial, four images from one object category and four images from a different category were presented on the screen. The images were always typical exemplars of their category. The images remained stationary for 4 s, after which they began moving around the display (see Fig. 2). The images moved diagonally along linear trajectories, occluding each other as they moved and bouncing off the edges of the display. Each image moved at a random rate between 60 and 150 pixels/s, and could change speed and direction randomly throughout the course of a trial. After 20 s, the images disappeared, and participants were asked to report the number of times members of one of the two categories bounced off the edges of the display. Participants received feedback on the

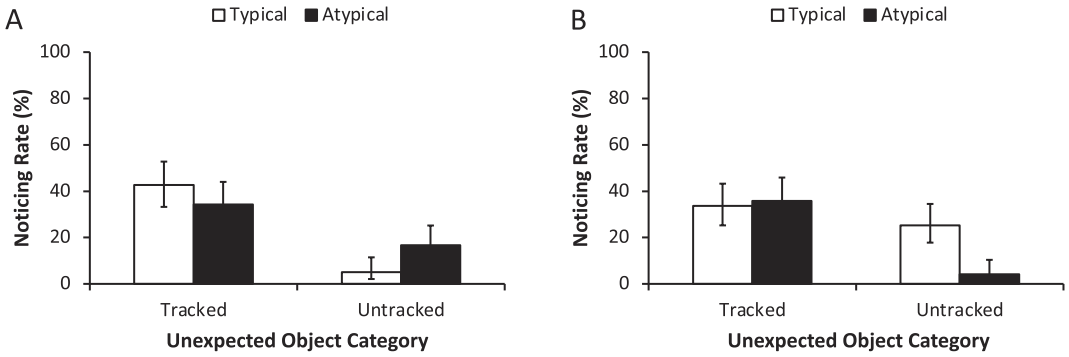

Fig. 3. (A) Noticing rates for the unexpected object in Experiment 1. (B) Noticing rates for the unexpected object in Experiment 2. Error bars in both panels represent 95% confidence intervals.

correct number of bounces on each trial. Although the two categories were randomly selected for each participant, participants always viewed the same two categories and always tracked members of the same category.

Participants completed a total of six trials. On the last trial, an unexpected image from one of the two categories entered from the right and moved horizontally across the display at a constant rate of 90 pixels/s. This unexpected object could belong to the same category as the tracked or untracked objects, and could be a typical or atypical exemplar of this category. The unexpected object was randomly selected from the full set of images of the two categories, with the constraint that participants did not view this image on any previous trial. After completing the last trial, participants were asked whether they noticed an unexpected object on this trial. Participants then reported whether the object was moving, its direction of movement (i.e., up, down, left, or right), and any additional details about the object. They also selected the identity of the object from the full list of object categories. If participants did not report noticing the object, they were asked to guess on each of these questions. Participants were coded as noticing the unexpected object if they answered all of these questions correctly.

After answering these questions, participants completed a survey about the quality of the task, the quality of their vision, and basic demographic information. We also tested whether participants were paying attention to our instructions. On one screen, participants were asked to select the middle item in a list of numbers and remember it for a future test. On the next screen, participants were asked to enter the number they selected. Participants failed this test if they selected an incorrect number on the first screen or entered an incorrect number on the second screen (these participants were excluded from analysis; see Table 1).

2.2. Results

Using logistic regression, we predicted noticing rates based on the category (tracked, untracked) and typicality of the unexpected object (typical, atypical). The analysis revealed a significant main effect of unexpected object category, Odds Ratio (OR) = 6.08, Z = 5.96, $p < .001$, with participants noticing the unexpected object more often when it belonged to the same category as the tracked objects (38.4%) compared to the untracked objects (10.9%). Thus, participants were more likely to notice objects that belonged to the same category as their current attentional set. However, there was no significant main effect of unexpected object typicality, OR = 1.63, Z = -1.62, p = .106. Importantly, these factors interacted, OR = 5.42, Z = 2.79, p = .005. Simple effects tests revealed that participants noticed atypical objects (16.7%) more often than typical objects (5.00%) when the unexpected object belonged to the same category as the untracked objects, OR = 3.80, Z = -2.52, p = .012. However, a similar effect was not observed when the unexpected object belonged to the same category as the tracked objects, OR = 1.43, Z = 1.21, p = .226. Error rates on the counting task did not differ as a function of the category or typicality of the unexpected object, all $ps \geq 0.170$. Thus, the present results were not due to differences in accuracy across conditions. Together, these results suggest that typicality modulated visual awareness for the untracked objects (see Fig. 3A).

2.3. Discussion

In Experiment 1, we found little evidence that typicality influenced visual awareness. Consistent with previous evidence, participants were more likely to notice objects that belonged to the same category as the tracked objects (Clement et al., 2019; Koivisto & Revonsuo, 2007; Most, 2013). However, participants were no more likely to notice typical members of this category. Interestingly, participants were more likely to notice atypical members of the untracked category. Thus, while typicality did not appear to influence visual awareness for the tracked objects, it did appear to influence visual awareness for the untracked objects. However, before accepting this conclusion, we must first rule out an alternative explanation for these findings.

3. Experiment 2

In Experiment 1, typicality appeared to modulate visual awareness for the untracked objects. However, participants always tracked

typical objects. Because typical and atypical objects were visually dissimilar from each other, it is possible that these findings were due to differences in visual similarity. Specifically, participants may have been more likely to notice atypical objects because they were visually dissimilar from the untracked objects (Drew & Stothart, 2016; Most et al., 2001). In Experiment 2, we assessed whether this was the case. Participants completed the same task as in Experiment 1. However, participants always tracked atypical objects. If the previous findings were due to typicality, we should observe the same pattern of results as in Experiment 1. However, if the previous findings were due to visual similarity, participants should be more likely to notice typical members of the untracked category.

3.1. Methods

3.1.1. Participants

A new group of 796 participants were recruited and tested online using Amazon Mechanical Turk; however, 396 participants were excluded for one or more of the reasons listed in Table 1. The remaining 400 participants (164 females; mean age = 36.4 years) were randomly assigned to one of four experimental conditions (see Table 2). All participants received $1.25 for participating in the experiment.

3.1.2. Apparatus and stimuli

The apparatus and stimuli were identical to those in the previous experiment.

3.1.3. Procedure

The task was the same as in Experiment 1, with the exception that the tracked and untracked objects were always atypical exemplars of their category. All other details of the experimental procedure were identical to those in the previous experiment.

3.2. Results

Using logistic regression, we again predicted noticing rates based on the category (tracked, untracked) and typicality of the unexpected object (typical, atypical). The analysis revealed a significant main effect of unexpected object category, $OR = 4.44$, $Z = 4.71$, $p < .001$, with participants noticing the unexpected object more often when it belonged to the same category as the tracked objects (34.7%) compared to the untracked objects (14.9%). Thus, participants were again more likely to notice objects that belonged to the same category as their current attentional set. There was also a significant main effect of unexpected object typicality, $OR = 2.69$, $Z = 3.12$, $p = .002$, with participants noticing typical objects (29.5%) more often than atypical ones (19.7%). Again, these factors interacted, $OR = 8.72$, $Z = -3.42$, $p < .001$. Simple effects tests revealed that participants noticed typical objects (25.2%) more often than atypical objects (4.08%) when the unexpected object belonged to the same category as the untracked objects, $OR = 7.94$, $Z = 3.71$, $p < .001$. However, a similar effect was not observed when the unexpected object belonged to the same category as the tracked objects, $OR = 1.10$, $Z = -0.32$, $p = .752$. Error rates on the counting task did not differ as a function of the category or typicality of the unexpected object, all $ps \geq 0.088$. Thus, the present results were not due to differences in accuracy across conditions. Again, these results suggest that typicality modulated visual awareness for the untracked objects (see Fig. 3B).

3.3. Discussion

In Experiment 2, we again found little evidence that typicality influenced visual awareness. As in the previous experiment, participants were more likely to notice objects that belonged to the same category as the tracked objects (Clement et al., 2019; Koivisto & Revonsuo, 2007; Most, 2013). However, participants were no more likely to notice typical members of this category. Moreover, unlike the previous experiment, participants were more likely to notice typical members of the untracked category. Notably, participants in this experiment always tracked atypical objects. Thus, participants were likely to notice typical objects because they were visually dissimilar from the untracked objects. Together, these findings suggest that the previous findings were due to visual similarity.

4. Experiment 3

In Experiments 1 and 2, we found little evidence that typicality influenced visual awareness. However, in both experiments, the unexpected object belonged to the same category as the tracked or untracked objects. Thus, the visual features of this object varied systematically with the other objects in the display, which may have masked the effects of typicality in these experiments. Previous studies have attempted to address this issue by having the unexpected object share a unique visual feature (Koivisto & Revonsuo, 2007; Most, 2013; Most et al., 2005; Most et al., 2001). In Experiment 3, we attempted to address this issue using a similar method. Participants completed the same task as in Experiment 1. However, the unexpected object could belong to the same category as the tracked objects or a new category that did not appear on any of the previous trials. If categorical attentional sets influence visual awareness, participants should be more likely to notice this object when it belongs to the same category as the tracked objects (Clement et al., 2019; Koivisto & Revonsuo, 2007; Most, 2013). Moreover, if typicality influences visual awareness, participants should be even more likely to notice this object when it is a typical exemplar of this category.

Table 3
Number of participants assigned to each experimental condition in Experiments 3 and 4.

	Exp. 3		Exp. 4	
Unexpected Object Category	Typical	Atypical	Typical	Atypical
Tracked	101 (25.3%)	91 (22.8%)	93 (23.3%)	97 (24.3%)
New	98 (24.5%)	110 (27.5%)	106 (26.5%)	104 (26.0%)

Note. Participants who were excluded from analysis are not reported here.

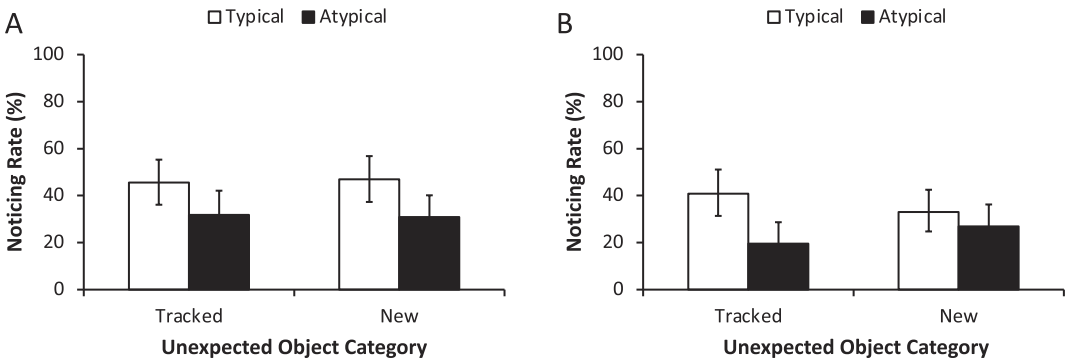

Fig. 4. (A) Noticing rates for the unexpected object in Experiment 3. (B) Noticing rates for the unexpected object in Experiment 4. Error bars in both panels represent 95% confidence intervals.

4.1. Methods

4.1.1. Participants

A new group of 790 participants were recruited and tested online using Amazon Mechanical Turk; however, 390 participants were excluded for one or more of the reasons listed in Table 1. The remaining 400 participants (162 females; mean age = 37.1 years) were randomly assigned to one of four experimental conditions (see Table 3). All participants received $1.25 for participating in the experiment.

4.1.2. Apparatus and stimuli

The apparatus and stimuli were identical to those in the previous experiments.

4.1.3. Procedure

The task was the same as in Experiment 1, with the exception that the unexpected object could belong to the same category as the tracked objects or a new category that did not appear on any of the previous trials. All other details of the experimental procedure were identical to those in the previous experiments.

4.2. Results

Using logistic regression, we again predicted noticing rates based on the category (tracked, new) and typicality of the unexpected object (typical, atypical). The analysis revealed a significant main effect of unexpected object typicality, $OR = 1.88$, $Z = 3.03$, $p = .002$, with participants noticing typical objects (46.2%) more often than atypical ones (31.3%). However, there was neither a significant main effect of unexpected object category, $OR = 1.01$, $Z = -0.03$, $p = .978$, nor a significant interaction between unexpected object category and unexpected object typicality, $OR = 1.11$, $Z = -0.24$, $p = .809$. Error rates on the counting task did not differ as a function of the category or typicality of the unexpected object, all $ps \geq 0.863$. Thus, the present results were not due to differences in accuracy across conditions. Together, these results suggest that typicality modulated visual awareness for both the tracked objects and a new category of objects (see Fig. 4A).

4.3. Discussion

In Experiment 3, we found clear evidence that typicality influenced visual awareness. Unlike the previous experiments, participants were no more likely to notice objects that belonged to the same category as the tracked objects. However, participants were more likely to notice typical members of both this category and the new category. Notably, members of the new category were visually dissimilar from both the tracked and untracked objects. Thus, participants were more likely to notice typical objects, even when they were

visually dissimilar from the other objects in the display. Together, these findings suggest that typicality influenced visual awareness for both the tracked objects and a new category of objects.

5. Experiment 4

In Experiment 3, typicality appeared to modulate visual awareness for both the tracked objects and a new category of objects. However, participants always tracked typical objects. While the effects of typicality for the new category cannot be attributed to visual similarity, it is possible that the effects of typicality for the tracked objects were due to differences in visual similarity. Specifically, participants may have been more likely to notice typical objects because they were visually similar to the tracked objects (Drew & Stothart, 2016; Most et al., 2005; Most et al., 2001; see also Simons & Chabris, 1999). In Experiment 4, we assessed whether this was the case. Participants completed the same task as in Experiment 3. However, participants always tracked atypical objects. If the previous findings were due to typicality, we should observe the same pattern of results as in Experiment 3. However, if the previous findings were due to visual similarity, participants should be more likely to notice atypical members of the tracked category.

5.1. Methods

5.1.1. Participants

A new group of 763 participants were recruited and tested online using Amazon Mechanical Turk; however, 363 participants were excluded for one or more of the reasons listed in Table 1. The remaining 400 participants (176 females; mean age = 38.0 years) were randomly assigned to one of four experimental conditions (see Table 3). All participants received $1.25 for participating in the experiment.

5.1.2. Apparatus and stimuli

The apparatus and stimuli were identical to those in the previous experiments.

5.1.3. Procedure

The task was the same as in Experiment 3, with the exception that the tracked and untracked objects were always atypical exemplars of their category. All other details of the experimental procedure were identical to those in the previous experiments.

5.2. Results

Using logistic regression, we again predicted noticing rates based on the category (tracked, new) and typicality of the unexpected object (typical, atypical). The analysis revealed a significant main effect of unexpected object typicality, $OR = 1.95$, $Z = 2.97$, $p = .003$, with participants noticing typical objects (36.7%) more often than atypical ones (23.4%). However, there was neither a significant main effect of unexpected object category, $OR = 1.04$, $Z = -0.17$, $p = .865$, nor a significant interaction between unexpected object category and unexpected object typicality, $OR = 2.12$, $Z = 1.67$, $p = .094$. Error rates on the counting task did not differ as a function of the category or typicality of the unexpected object, all $ps \geq 0.167$. Thus, the present results were not due to differences in accuracy across conditions. Again, these results suggest that typicality modulated visual awareness for both the tracked objects and a new category of objects (see Fig. 4B).

5.3. Discussion

In Experiment 4, we again found clear evidence that typicality influenced visual awareness. As in the previous experiment, participants were no more likely to notice objects that belonged to the same category as the tracked objects. However, participants were more likely to notice typical members of both this category and the new category. Notably, participants in this experiment always tracked atypical objects. Thus, participants were more likely to notice typical objects, even when they were visually dissimilar from the tracked objects. Together, these findings suggest that the previous findings were due to typicality rather than visual similarity.

6. General discussion

In the present study, we assessed whether typicality can influence the visual awareness of objects. Participants tracked moving images of objects and counted how often members of one category bounced off the edges of the display. On the last trial, an unexpected object moved across the display. In our first two experiments, this object could belong to the same category as the tracked or untracked objects. Consistent with previous evidence, participants were more likely to notice this object when it belonged to the same category as the tracked objects (Clement et al., 2019; Koivisto & Revonsuo, 2007; Most, 2013). However, while participants were more likely to notice atypical members of the untracked category, this pattern of results reversed when participants tracked atypical objects. In our last two experiments, the unexpected object could belong to the same category as the tracked objects or a new category of objects. Unlike the previous experiments, participants were no more likely to notice objects that belonged to the same category as the tracked objects. However, participants were more likely to notice typical members of both this category and the new category. Together, these findings suggest that typicality can modulate the visual awareness of objects, but only when the visual features of the unexpected object do not vary systematically with the other objects in the display.

Overall, the present findings provide clear evidence that typicality can influence visual awareness. Previous evidence suggests that typicality can influence the guidance of attention. For example, typicality has been found to influence visual search (Maxfield et al., 2014; Robbins & Hout, 2020; but see Castelhano et al., 2008) and attentional capture by object categories (Lim et al., 2021). In our last two experiments, participants were more likely to notice typical members of both the tracked category and the new category. Critically, this pattern of results was observed even when participants tracked atypical objects. While a similar pattern of results was not observed in our first two experiments, this is likely because the visual features of the unexpected object varied systematically with the other objects in the display. Thus, participants were more likely to notice objects that were visually dissimilar from the untracked objects, which may have masked the effects of typicality in these experiments. Together, these findings suggest that typicality plays an important role in the visual awareness of objects.

In addition to the effects of typicality, the present findings also provide clear evidence that categorical attentional sets can influence visual awareness. A growing body of research suggests that observers can adopt attentional sets for a particular semantic category (Nako et al., 2014; Wu et al., 2013; Wyble et al., 2013; Yang & Zelinsky, 2009). When observers adopt a categorical attentional set, members of this category can capture attention (Wyble et al., 2013) and are more likely to enter awareness (Clement et al., 2019; Koivisto & Revonsuo, 2007; Most, 2013). In our first two experiments, participants were more likely to notice objects that belonged to the same category as the tracked objects. This pattern of results was observed for both typical and atypical members of this category, suggesting that these effects can occur even when the unexpected object is visually dissimilar from the tracked objects. Moreover, this pattern of results was observed even when participants tracked atypical objects. While a similar pattern of results was not observed in our last two experiments, this is likely because members of the new category were visually dissimilar from both the tracked and untracked objects. Thus, participants were more likely to notice these objects because they were visually dissimilar from the other objects in the display, which may have masked the effects of categorical attentional sets in these experiments. Together, these findings suggest that categorical attentional sets play an important role in the visual awareness of objects.

Lastly, the present findings are consistent with previous evidence that visual similarity can influence visual awareness. Critically, both similarity to the tracked objects and dissimilarity from the untracked objects have been found to modulate the visual awareness of objects. For example, when observers adopt an attentional set for a particular color, they are more likely to notice objects that are similar to this color (Drew & Stothart, 2016; Most et al., 2005; Most et al., 2001; see also Simons & Chabris, 1999). Similarly, when participants are asked to ignore a particular color, they are more likely to notice objects that are dissimilar from this color (Drew & Stothart, 2016; Most et al., 2001). In our first two experiments, participants were more likely to notice atypical members of the untracked category. However, this pattern of results reversed when participants tracked atypical objects. Together, these findings suggest that typicality does not influence visual awareness for the untracked objects. Instead, observers are more likely to notice objects that are visually dissimilar from the untracked objects.

Based on the present findings, we assume that participants adopted a categorical attentional set. However, because members of the same category are more visually similar than members of different categories, it is possible that participants tracked objects based on their visual features rather their semantic category. Thus, participants may have been more likely to notice objects that belonged to the same category as their current attentional set because these objects were visually similar to the tracked objects (Drew & Stothart, 2016; Most et al., 2005; Most et al., 2001; see also Simons & Chabris, 1999). While this explanation is plausible, we think it is unlikely that the present findings were purely due to visual similarity. In our last two experiments, participants were more likely to notice typical members of the tracked category. Critically, this pattern of results was observed even when participants tracked atypical objects. This contrasts with the clear effects of visual similarity observed for the untracked objects. If the present findings were purely due to visual similarity, we would expect similar effects to occur for the tracked objects. Thus, while visual similarity influenced visual awareness for the untracked objects, it did not appear to influence visual awareness for the tracked objects.

In addition to the effects of visual similarity, it is possible that participants fixated the unexpected object more often in some conditions than others. Previous evidence suggests that distance from fixation plays an important role in the visual awareness of objects. For example, participants are more likely to notice objects that appear closer to fixation (Mack & Rock, 1998; Most, Simons, Scholl, & Chabris, 2000; Newby & Rock, 1998). Because we did not track participants' eye movements, we cannot determine where participants were looking. However, we think it is unlikely that the present findings were due to differences in fixating the unexpected object across conditions. In all of our experiments, the unexpected object moved across the center of the display and remained on the screen for 7.4 s. Thus, assuming that participants fixated near the center of the display, it is likely that this object crossed into central vision. The unexpected object also followed the same trajectory for all participants. Thus, participants should not have been more likely to fixate this object across conditions. Nonetheless, future research should attempt to address this issue by tracking participants' eye movements.

In summary, we found that typicality can influence the visual awareness of objects. In our first two experiments, participants were more likely to notice objects that belonged to the same category as the tracked objects. However, while participants were more likely to notice atypical members of the untracked category, this pattern of results reversed when participants tracked atypical objects. In our last two experiments, participants were no more likely to notice objects that belonged to the same category as the tracked objects. However, participants were more likely to notice typical members of both this category and the new category. Together, these findings provide converging evidence for the effects of typicality on attention, and suggest that typicality plays an important role in the visual awareness of objects.

CRediT authorship contribution statement

Andrew Clement: Conceptualization, Formal analysis, Investigation, Writing – original draft. **Y. Isabella Lim:** Conceptualization,

Table 4
Average typicality ratings for each object category in the present study.

Category	Typical	Atypical
Airplane	6.45	4.53
Axe	6.05	4.67
Bed	6.23	5.15
Bench	6.16	4.73
Bicycle	6.26	3.63
Bird	6.32	4.15
Bottle	5.99	3.84
Car	6.27	3.77
Cat	6.3	3.77
Chair	6.23	4.34
Clock	5.82	4.17
Dog	6.29	4.77
Fish	6.42	3.73
Guitar	6.39	4.81
Gun	6.38	3.42
Hammer	6.21	3.93
Hat	6.27	3.63
Lamp	6.03	4.7
Mushroom	5.99	3.62
Scissors	6.3	3.44
Shoe	6.31	4.83
Stapler	6.32	4.76
Telephone	5.75	3.11
Tree	6.01	5.06

Notes. Typicality was rated using a 7-point Likert scale (1 = highly atypical, 7 = highly typical). Differences between typical and atypical exemplars were significant for all categories at the $p < .001$ level.

Writing – review & editing. **Cary Stothart:** Methodology, Software, Writing – review & editing. **Jay Pratt:** Conceptualization, Funding acquisition, Supervision, Writing – review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Data Statement.

The materials, analyses, and data from all of our experiments are available on the Open Science Framework (https://osf.io/wn3z6/).

Author Note.

The opinions, interpretations, conclusions, and recommendations are those of the authors and are not necessarily endorsed by the U.S. Army.

Appendix

Table 4.

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