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Semantic associations do not modulate the visual awareness of objects

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Abstract

When observers adopt a category-level attentional set, objects that belong to the same category as this attentional set are more likely to enter awareness. For example, a driver who is monitoring the road for cars may be more likely to notice an oncoming car than a pedestrian who is crossing the road. Semantic associations between categories are also known to influence the deployment of attention, but it is unclear whether these associative relationships can influence the visual awareness of objects. To address this issue, we conducted four experiments using an inattentional blindness task. Participants tracked moving images of animals (e.g., monkeys or rabbits). On the last trial, an unexpected object that could belong to the same category as the tracked objects (i.e., a monkey or rabbit) or a semantically associated category (i.e., a banana or carrot) moved across the display. Participants were more likely to notice this object when it was visually salient or belonged to the same category as the tracked objects. However, they were no more likely to notice objects that shared a semantic association with the tracked objects. Thus, although categorical relationships play an important role in the visual awareness of objects, this effect does not extend to associative relationships among objects.

Keywords

Visual awareness; attentional sets; semantic associations; inattentional blindness

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Introduction

Most people assume that simply looking at an object guarantees awareness of that object. However, as research on inattentional blindness (Mack & Rock, 1998; Simons & Chabris, 1999), change blindness (Rensink, O'Regan, & Clark, 1997; Simons & Levin, 1997), and selective looking (Neisser & Becklen, 1975) demonstrate, observers often fail to notice salient objects, especially when they are unexpected in the context of observers' task. Why do we fail to notice objects that are plainly in view? As the previous literature suggests, focused attention is often necessary for objects to enter awareness. In fact, many of the factors that influence attentional deployment are also known to modulate the visual awareness of objects. For example, the visual salience of objects (Most, Clifford, Scholl, & Simons, 2005), the difficulty of observers' task (Cartwright-Finch & Lavie, 2007), and observers' task goals (Most et al., 2001) all play an important role in the conscious awareness of objects.

One factor that strongly influences visual awareness is observers' *attentional set*, which is the set of features that observers prioritise for attentional selection (e.g., Folk, Remington, & Johnston, 1992). For example, when observers tune their attention to a particular colour, they are more likely to notice objects that share this colour (Most et al., 2005; Most et al., 2001, see also Simons & Chabris, 1999). Observers can also tune their attention to a particular semantic category. For example, a driver who is scanning the road may adopt an attentional set for cars, regardless of their specific visual features. When observers adopt such category-level attentional sets, objects that belong to the same category as this attentional set are more likely to enter awareness. For example, in one study, participants viewed moving images of letters and numbers,

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and tracked how often members of one stimulus category bounced off the edges of the display (Most, 2013). On the last trial, an unexpected image of a letter or number moved across the display. Participants were more likely to notice this object when it belonged to the same category as the tracked objects (see also Koivisto & Revonsuo, 2007). Based on these findings, it is clear that categorical relationships can support the conscious awareness of objects. What is less clear is how other types of semantic relationships might influence awareness.

When observers adopt a category-level attentional set, members of this category often share semantic relationships with other objects in the environment. Consider the example of a driver monitoring the road for cars. In this case, would adopting a category-level attentional set for cars influence the awareness of semantically related objects, such as road signs, traffic signals, or even pedestrians? Although all of these objects share a semantic relationship with cars, they are not members of the same semantic category. Instead, while cars are related by their shared perceptual and semantic features (a *categorical relationship*), cars and pedestrians are related by their participation in the same situations and events (an *associative relationship*).[1] Although previous work suggests that categorical relationships can influence the visual awareness of objects (Koivisto & Revonsuo, 2007; Most, 2013), the goal of the present study was to assess whether these effects extend to associative relationships among objects.

Unlike categorical relationships, relatively little is known about the effects of associative relationships on visual awareness. However, these relationships are known to influence the deployment of attention. For example, Moores, Laiti, and Chelazzi (2003) found that when participants searched for a target object (e.g., a monkey) in a visual search display, they were more likely to fixate objects that belonged to a semantically associated category (e.g., a banana; see also Belke, Humphreys, Watson, Meyer, & Telling, 2008; Meyer, Belke, Telling, & Humphreys, 2007; Telling, Kumar, Meyer, & Humphreys, 2010). Similar findings have been observed in real-world scenes (Hwang, Wang, & Pomplun, 2011; Wu, Wick, & Pomplun, 2014). Together, these findings suggest that when observers adopt a category-level attentional set, objects that share a semantic association with this attentional set become prioritised for attention. Because attention is necessary for objects to enter awareness, these associations may also support the conscious awareness of objects.

Notably, the previous findings are consistent with many models of semantic memory. When observers adopt a category-level attentional set, members of that category become activated in memory. This activation is thought to spread to members of semantically related categories, priming these objects for further processing (e.g., Anderson, 1983; Collins & Loftus, 1975). However, this activation becomes increasingly attenuated as it spreads to other categories. Thus, although this activation may be strong enough to influence attention, it may not be strong enough to modulate the visual awareness of objects. Such an outcome would be consistent with the inattentional blindness literature, which suggests that attention is not always sufficient for objects to enter awareness (Simons, 2000). Indeed, observers often fail to notice salient objects, even when these objects are known to implicitly capture attention. Thus, although semantic associations are known to influence attentional deployment, these associations may not be strong enough for objects to enter awareness.

To assess whether associative relationships influence visual awareness, we conducted four experiments using an inattentional blindness task. Participants viewed moving images of animals (e.g., monkeys or rabbits), and tracked how often members of one stimulus category bounced off the edges of the display. On the last trial, an unexpected object moved across the display. This object could either belong to the same category as the tracked objects (e.g., a monkey), a different category of objects (e.g., a rabbit), a semantically associated category (e.g., a banana), or a semantically unrelated category (e.g., a carrot). Previous work suggests that categorical relationships among objects can influence visual awareness (Koivisto & Revonsuo, 2007; Most, 2013). If associative relationships also influence awareness, participants should be more likely to notice objects that share a semantic association with their current attentional set. However, if associative relationships do not influence awareness, participants should be no more likely to notice these objects.

Experiment 1

In most inattentional blindness studies, participants view relatively simple stimuli, such as coloured letters or shapes (e.g., Most et al., 2001). In the present study, participants viewed members of real-world semantic categories. Thus, before assessing the role of associative relationships in visual awareness, we first sought to replicate the effects of categorical relationships using these stimuli (Koivisto & Revonsuo, 2007; Most, 2013). Participants tracked moving images of monkeys or rabbits. On the last trial, an unexpected image of a monkey or rabbit moved across the display. If categorical relationships modulate visual awareness, participants should be more likely to notice this object when it belongs to the same category as the tracked objects. However, if categorical relationships do not modulate visual awareness, participants should be no more likely to notice this object.

Methods

The materials, analyses, and data from all of our experiments are available on the Open Science Framework

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

Exclusion rule	Experiment 1	Experiment 2	Experiment 3	Experiment 4
Already participated in the present experiment	37 (6.75%)	44 (5.93%)	14 (2.66)	13 (1.98%)
Participated in one of the previous experiments	0 (0%)	142 (19.1%)	0 (0%)	150 (22.8%)
Reported not having normal or corrected-to-normal vision	42 (7.66%)	48 (6.47%)	38 (7.22%)	38 (5.78%)
Failed a colour-blindness test	12 (2.19%)	28 (3.77%)	15 (2.85%)	14 (2.13%)
Failed to pay attention to the instructions	15 (2.74%)	29 (3.91%)	27 (5.13%)	23 (3.50%)
Entered a nonsensical open response or reported that the task did not work correctly	8 (1.46%)	18 (2.43%)	16 (3.04%)	15 (2.28%)
Reported being familiar with the inattentional blindness task	62 (11.3%)	157 (21.2%)	54 (10.3%)	68 (10.3%)
Total excluded	127 (23.2%)	343 (46.2%)	125 (23.8%)	243 (36.9%)

Participants could be excluded for multiple reasons.

Table 2. Number of participants assigned to each experimental condition in Experiments 1 to 3.

Tracked objects	Experiment 1		Experiment 2		Experiment 3	
	Monkey	Rabbit	Banana	Carrot	Banana	Carrot
Monkeys	105 (24.9%)	103 (24.5%)	103 (25.8%)	96 (24.1%)	98 (24.4%)	107 (26.7%)
Rabbits	105 (24.9%)	108 (25.7%)	97 (24.3%)	103 (25.8%)	97 (24.2%)	99 (24.7%)

Participants who were excluded from analysis are not reported here.

(https://osf.io/maqwk/). The procedure and exclusion criteria for each experiment were based on previous inattentional blindness studies (e.g., Drew & Stothart, 2016; Stothart, Boot, & Simons, 2015).

Participants. Participants were recruited and tested online using Amazon Mechanical Turk. Data were collected from a total of 548 participants; however, 127 participants were excluded for one or more of the reasons listed in Table 1. The remaining 421 participants (278 females; mean age = 36.4 years) were randomly assigned to one of four experimental conditions (see Table 2). All participants received $0.25 for participating in the experiment.

Apparatus and stimuli. Stimuli consisted of 18 images of animals (9 monkeys, 9 rabbits). To reduce any differences in colour across images, the images were presented in greyscale. The images were also matched in luminance. All images subtended approximately 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.

Procedure. On each trial, a random set of four monkeys and four rabbits were presented on the screen. The images remained stationary for 4 s, after which they began moving around the display (see Figure 1). The images moved 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 the monkeys or rabbits bounced off the edges of the display. Participants received feedback on each trial.

Participants completed a total of six trials. On the last trial, an unexpected image of a monkey or rabbit entered from the right and moved horizontally across the display at a rate of 90 pixels/s. This unexpected object was randomly selected from the set of 18 images, 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, and any additional details about the object. They also selected the identity of the object from a list of filler objects (e.g., rock, tree, bird, airplane, etc.). 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 at least one of these questions correctly.[2]

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

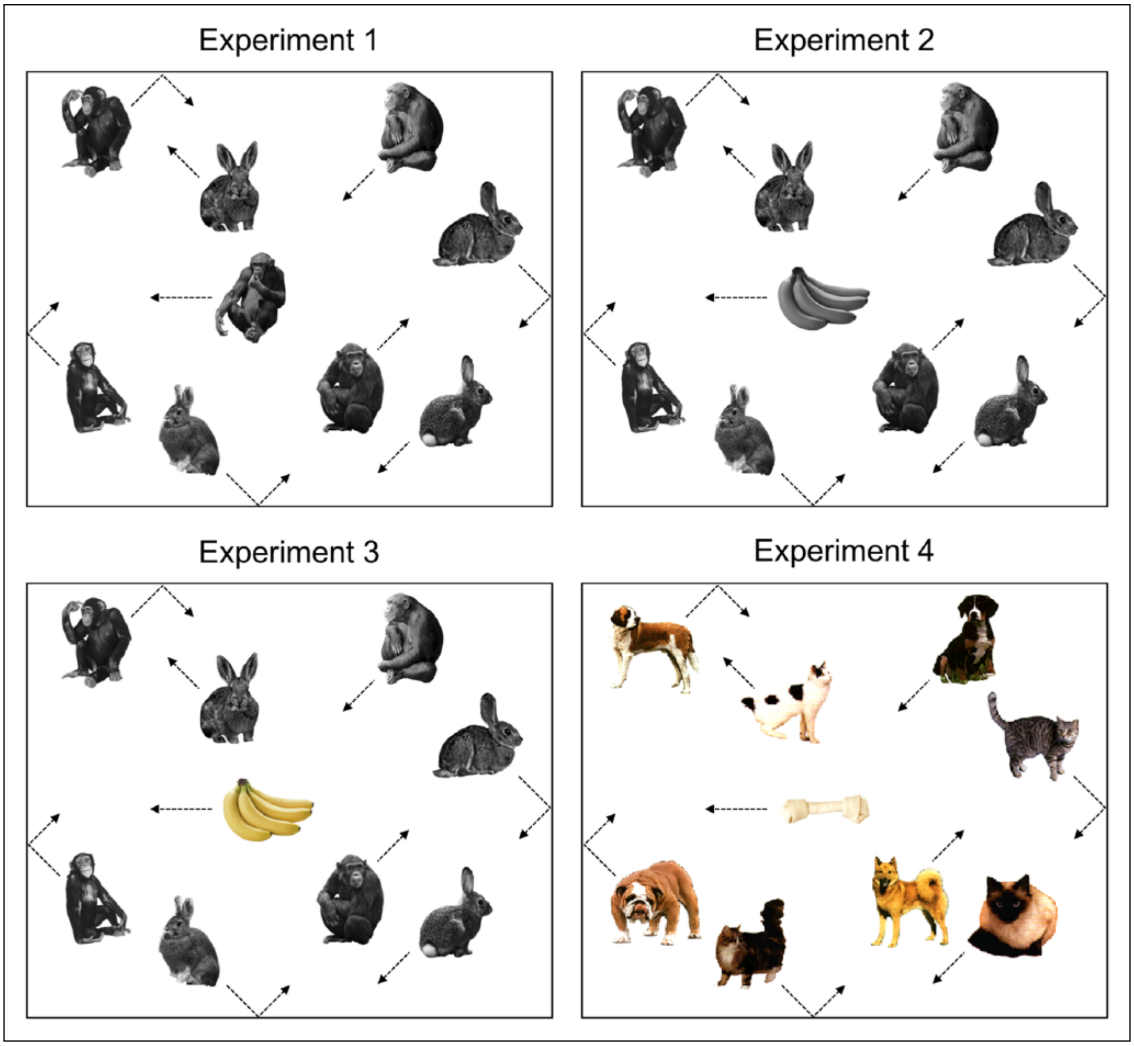

Figure 1. The inattentional blindness task used in the present study. The horizontally moving object in each panel represents the unexpected object, which only appeared on the last trial. This object was presented in colour in Experiment 3, and both the tracked objects and unexpected object were presented in colour in Experiment 4.

entered an incorrect number on the second screen (these participants were excluded from analysis; see Table 1). On average, the entire experiment took 7.5 min to complete.

Results

Using logistic regression, we predicted noticing rates based on the category of the tracked objects (monkeys, rabbits) and the identity of the unexpected object (monkey, rabbit). The analysis revealed a significant main effect of tracked objects, odds ratio (OR) = 2.61, $Z = -2.66$, $p = .008$, with participants who tracked monkeys (21.6%) noticing the unexpected object slightly more often than those who tracked rabbits (20.2%). We also observed a significant main effect of unexpected object, OR = 2.34, $Z = -2.42$, $p = .016$, with participants noticing unexpected monkeys (21.0%) slightly more often than unexpected rabbits (20.9%). However, these factors interacted, OR = 5.59, $Z = 3.42$, $p < .001$. Simple effects tests revealed that participants who tracked monkeys noticed unexpected monkeys (28.6%) more often than unexpected rabbits (14.6%), OR = 2.34, $Z = -2.42$, $p = .016$, while participants who tracked rabbits noticed unexpected rabbits (26.9%) more often than unexpected monkeys (13.3%), OR = 2.39, $Z = 2.42$, $p = .016$. Thus, participants were more likely to notice objects that belonged to the same category as their current attentional set (see Figure 2).

Discussion

In Experiment 1, we replicated the effects of categorical relationships on visual awareness (Koivisto & Revonsuo, 2007; Most, 2013). Specifically, participants who tracked monkeys were more likely to notice an unexpected monkey, while participants who tracked rabbits were more likely to notice an unexpected rabbit. Overall noticing rates

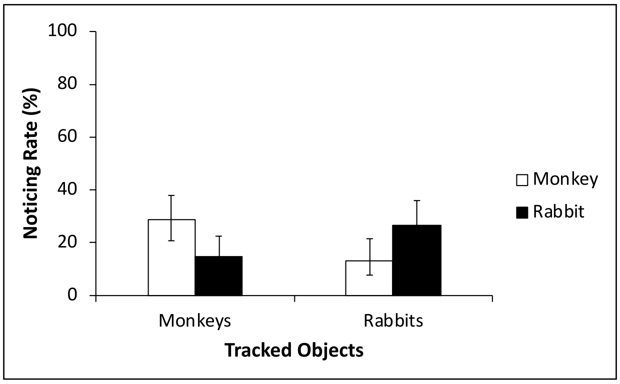

Figure 2. Noticing rates for the unexpected object in Experiment 1. Error bars represent 95% confidence intervals.

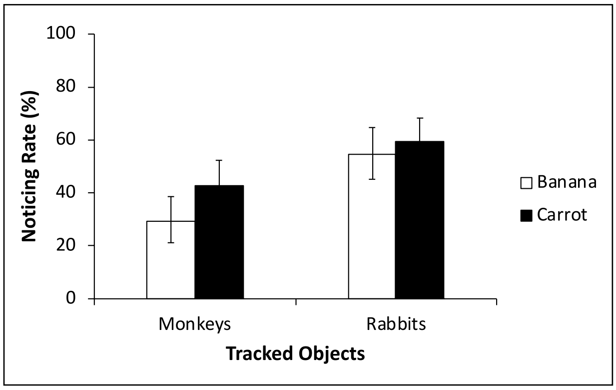

Figure 3. Noticing rates for the unexpected object in Experiment 2. Error bars represent 95% confidence intervals.

were relatively low, which may have been due to the perceptual similarity between the tracked objects and unexpected object. However, as Most (2013) found, the effects of categorical relationships can be observed regardless of whether the unexpected objects are perceptually similar to the tracked objects or share a unique visual feature. Having demonstrated these effects, our second experiment tested whether category-level attentional sets influence visual awareness for semantically associated categories.

Experiment 2

In Experiment 2, we assessed whether associative relationships modulate visual awareness. In Experiment 1, the unexpected objects belonged to the same category as the tracked objects. However, both monkeys and rabbits share strong semantic associations with members of other categories. To test whether these associations influence visual awareness, we used images of a banana and a carrot as unexpected objects. If associative relationships modulate visual awareness, participants should be more likely to notice these objects when they share a semantic association with the tracked objects. However, if associative relationships do not modulate visual awareness, participants should be no more likely to notice these objects.

Methods

Participants. Data were collected from a total of 742 participants using Amazon Mechanical Turk; however, 343 participants were excluded for one or more of the reasons listed in Table 1. The remaining 399 participants (260 females; mean age = 35.4 years) were randomly assigned to one of four experimental conditions (see Table 2). All participants received $0.25 for participating in the experiment.

Apparatus and stimuli. Stimuli consisted of a subset of 16 images from Experiment 1 (8 monkeys, 8 rabbits). Greyscale images of a banana and carrot served as unexpected objects. All other details of the apparatus and stimuli were identical to those in the previous experiment.

Procedure. The task was the same as in Experiment 1, with the exception that a greyscale image of a banana or carrot moved across the display on the last trial. All other details of the experimental procedure were identical to those in the previous experiment.

Results

Using logistic regression, we again predicted noticing rates based on the category of the tracked objects (monkeys, rabbits) and the identity of the unexpected object (banana, carrot). The analysis revealed a significant main effect of tracked objects, OR = 2.95, $Z = 3.61$, $p < .001$, with participants who tracked rabbits (57.0%) noticing the unexpected object more often than those who tracked monkeys (35.7%). We also observed a significant main effect of unexpected object, OR = 1.82, $Z = 1.99$, $p = .047$, with participants noticing unexpected carrots (51.3%) more often than unexpected bananas (41.5%). However, these factors did not interact, OR = –1.50, $Z = –0.41$, $p = .324$. Thus, although properties of the tracked objects and unexpected object influenced noticing rates, participants were no more likely to notice objects that shared a semantic association with their current attentional set (see Figure 3).

To compare these results with Experiment 1, we next predicted noticing rates based on experiment (Experiment 1, Experiment 2), tracked objects (monkeys, rabbits), and unexpected object (monkey-related, rabbit-related). Again, we observed significant main effects of both tracked objects, OR = 2.95, $Z = 3.61$, $p < .001$, and unexpected object, OR = 1.82, $Z = 1.99$, $p = .047$. Although tracked objects, OR = 7.61, $Z = –4.35$, $p < .001$, and unexpected object, OR = 4.26, $Z = –3.13$, $p = .002$, both interacted with experiment, these effects were qualified by a significant three-way interaction between experiment, tracked objects, and unexpected object, OR = 8.42, $Z = 3.27$, $p < .001$. Whereas tracked objects and unexpected object interacted in Experiment 1, these factors did not interact in Experiment 2. No other effects were significant, all *p*s ≥ .324.

Discussion

In Experiment 2, we found no evidence that associative relationships influence visual awareness. In this case, participants who tracked monkeys were no more likely to notice an unexpected banana, and participants who tracked rabbits were no more likely to notice an unexpected carrot. Although properties of both the tracked objects and unexpected object influenced noticing rates, these effects were not in the predicted direction and did not interact. Together, these findings suggest that category-level attentional sets do not influence visual awareness for semantically associated categories.

Experiment 3

In Experiment 3, we further assessed whether associative relationships modulate visual awareness. In the previous experiments, the unexpected objects were always presented in greyscale. However, both bananas and carrots are strongly associated with a particular colour. To confirm that Experiment 2's results were not due to the lack of common colour associations, we presented the unexpected objects in colour. If associative relationships influence visual awareness, participants should be more likely to notice these objects when they share a semantic association with the tracked objects. However, if associative relationships do not modulate visual awareness, participants should be no more likely to notice these objects. Compared with the results of Experiment 2, participants should also be more likely to notice coloured unexpected objects, as these objects are more visually salient (Most et al., 2005).

Methods

Participants. Data were collected from a total of 526 participants using Amazon Mechanical Turk; however, 125 participants were excluded for one or more of the reasons listed in Table 1. The remaining 401 participants (249 females; mean age = 36.7 years) were randomly assigned to one of four experimental conditions (see Table 2). All participants received $0.25 for participating in the experiment.

Apparatus and stimuli. Stimuli consisted of the same 16 images from Experiment 2. Coloured images of a banana and carrot served as unexpected objects. All other details of the apparatus and stimuli were identical to those in the previous experiments.

Procedure. The task was the same as in Experiment 2, with the exception that a coloured image of a banana or carrot moved across the display on the last trial. All other details of the experimental procedure were identical to those in the previous experiments.

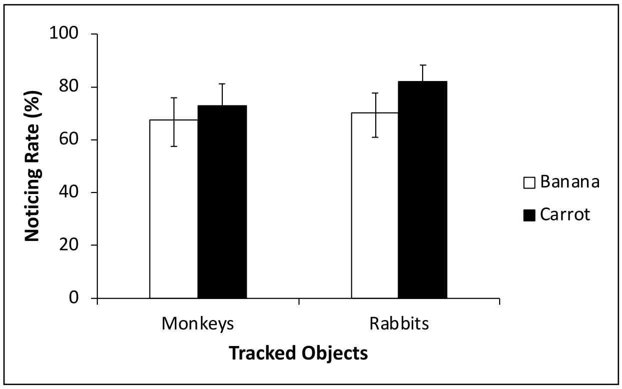

Figure 4. Noticing rates for the unexpected object in Experiment 3. Error bars represent 95% confidence intervals.

Results

Using logistic regression, we again predicted noticing rates based on the category of the tracked objects (monkeys, rabbits) and the identity of the unexpected object (banana, carrot). However, we observed no significant main effect of tracked objects, OR = 1.14, Z = 0.42, p = .678, or unexpected object, OR = 1.30, Z = 0.87, p = .386. These factors did not interact, OR = 1.47, Z = 0.84, p = .400. Thus, as in Experiment 2, participants were no more likely to notice objects that shared a semantic association with their current attentional set (see Figure 4).

To compare these results with Experiment 2, we next predicted noticing rates based on experiment (Experiment 2, Experiment 3), tracked objects (monkeys, rabbits), and unexpected object (monkey-related, rabbit-related). Importantly, we observed a significant main effect of experiment, OR = 5.02, Z = 5.28, $p < .001$, with participants in Experiment 3 (73.1%) noticing the unexpected object more often than those in Experiment 2 (46.4%). Thus, participants were more likely to notice salient unexpected objects. As in Experiment 2, we observed significant main effects of both tracked objects, OR = 2.93, Z = 3.61, $p < .001$, and unexpected object, OR = 1.81, Z = 1.99, p = .047. However, tracked objects, OR = 2.56, Z = –2.21, p = .027, but not unexpected object, OR = 1.39, Z = –0.77, p = .441, interacted with experiment, suggesting that these effects were partly driven by the results of Experiment 2. No other effects were significant, all *p*s ≥ .199.

Discussion

In Experiment 3, we again found no evidence that associative relationships influence visual awareness. As in Experiment 2, participants who tracked monkeys were no

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

Tracked objects	Bone	Yarn
Dogs	104 (25.1%)	97 (23.4%)
Cats	105 (25.3%)	109 (26.3%)

Participants who were excluded from analysis are not reported here.

more likely to notice an unexpected banana, and participants who tracked rabbits were no more likely to notice an unexpected carrot. Properties of the tracked objects and unexpected object did not influence noticing rates, suggesting that these effects were specific to Experiment 2. Moreover, consistent with previous evidence, participants were more likely to notice visually salient objects (Most et al., 2005). Together, these findings suggest that category-level attentional sets do not influence visual awareness for semantically associated categories.

Experiment 4

In Experiment 4, we further assessed whether associative relationships modulate visual awareness. In the previous experiments, we used stimuli that shared a specific set of semantic associations. However, it is possible that these associations were not sufficient to influence awareness. Moreover, the perceptual dissimilarity between monkeys and rabbits may have led participants to track objects based on their visual features rather than their semantic category. To confirm that the previous results were not due to our choice of stimuli, we sought to replicate these findings using a more perceptually similar set of stimuli. Participants tracked moving images of dogs or cats. On the last trial, an unexpected image of a bone or ball of yarn moved across the display. If associative relationships modulate visual awareness, participants should be more likely to notice this object when it shares a semantic association with the tracked objects. However, if associative relationships do not modulate visual awareness, participants should be no more likely to notice this object.

Methods

Participants. Data were collected from a total of 658 participants using Amazon Mechanical Turk; however, 243 participants were excluded for one or more of the reasons listed in Table 1. The remaining 415 participants (267 females; mean age = 35.9 years) were randomly assigned to one of four experimental conditions (see Table 3). All participants received $0.25 for participating in the experiment.

Apparatus and stimuli. Stimuli consisted of 36 coloured images of animals (18 dogs, 18 cats). Coloured images of a bone and ball of yarn served as unexpected objects. To reduce any differences in colour across images, the unexpected objects were presented in the same colour. All other details of the apparatus and stimuli were identical to those in the previous experiments.

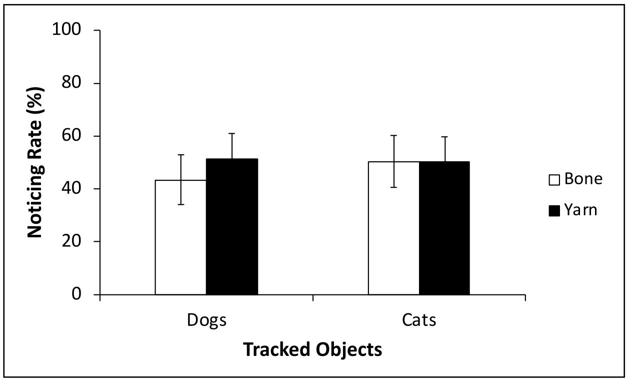

Figure 5. Noticing rates for the unexpected object in Experiment 4. Error bars represent 95% confidence intervals.

Procedure. The task was the same as in the previous experiments, with the exception that participants were asked to report the number of times the dogs or cats bounced off the edges of the display. A coloured image of a bone or ball of yarn moved across the display on the last trial. All other details of the experimental procedure were identical to those in the previous experiments.

Results

Using logistic regression, we again predicted noticing rates based on the category of the tracked objects (dogs, cats) and the identity of the unexpected object (bone, yarn). However, we observed no significant main effect of tracked objects, OR = 1.04, $Z = 0.16$, $p = .876$, or unexpected object, OR = 1.00, $Z < 0.01$, $p = .998$. These factors did not interact, OR = 1.39, $Z = –0.85$, $p = .397$. Thus, as in the previous experiments, participants were no more likely to notice objects that shared a semantic association with their current attentional set (see Figure 5).

Discussion

In Experiment 4, we again found no evidence that associative relationships influence visual awareness. Consistent with the previous experiments, participants who tracked dogs were no more likely to notice an unexpected bone, and participants who tracked cats were no more likely to notice an unexpected ball of yarn. Properties of the tracked objects and unexpected object again did not influence noticing rates. Along with the previous results, these findings suggest that category-level attentional sets do not influence visual awareness for semantically associated categories.

General discussion

When observers adopt a category-level attentional set, objects that belong to the same category as this attentional set are more likely to enter awareness (Koivisto & Revonsuo, 2007; Most, 2013). Semantic associations between categories are also known to influence the deployment of attention, but it is unclear whether these associative relationships can influence the visual awareness of objects. To address this issue, we conducted four experiments using an inattentional blindness task. Participants tracked moving images of animals (e.g., monkeys or rabbits). On the last trial, an unexpected object that could belong to the same category as the tracked objects (i.e., a monkey or rabbit) or a semantically associated category (i.e., a banana or carrot) moved across the display. Consistent with previous evidence, participants were more likely to notice this object when it was visually salient (Most et al., 2005) or belonged to the same category as the tracked objects (Koivisto & Revonsuo, 2007; Most, 2013). However, they were no more likely to notice objects that shared a semantic association with the tracked objects. Thus, although categorical relationships modulated the visual awareness of objects, associative relationships did not.

Overall, our findings suggest that associative relationships do not support the conscious awareness of objects. This is surprising, given that these relationships are known to influence attentional deployment in both visual search displays (Moores et al., 2003; see also Belke et al., 2008; Meyer et al., 2007; Telling et al., 2010) and real-world scenes (Hwang et al., 2011; Wu et al., 2014). In such cases, observers are more likely to attend to objects that share a semantic association with their current attentional set. However, observers often fail to notice salient objects, even when those objects are known to implicitly capture attention (Simons, 2000). Based on such findings, the factors that influence attention do not always lead to the conscious awareness of objects. Instead, attention appears to be a necessary but not sufficient condition for awareness. According to this view, objects must receive a certain amount of activation to reach the threshold for awareness (Cohen, Cavanagh, Chun, & Nakayama, 2012). In some cases, this activation may be strong enough to influence attention, but not strong enough to modulate visual awareness. Thus, although associative relationships can influence attentional deployment, this may not be sufficient for objects to enter awareness.

In addition to the inattentional blindness literature, the present findings are consistent with many models of semantic memory. When observers adopt a category-level attentional set, activation spreads to members of semantically related categories (e.g., Anderson, 1983; Collins & Loftus, 1975). Because they belong to the same category as observers' attentional set, objects that share a categorical relationship with this attentional set become strongly activated in memory. As a result, these objects are prioritised for attention and are able to reach the threshold for awareness (Koivisto & Revonsuo, 2007; Most, 2013). However, because this activation becomes increasingly attenuated as it spreads to other categories, objects that share an associative relationship with observers' attentional set are activated less strongly. Thus, although these objects are prioritised for attention (Moores et al., 2003), they are not able to reach the threshold for awareness.

One alternative explanation for the present findings is that our task may have been too difficult for associative relationships to influence visual awareness. As models of perceptual load suggest, task-irrelevant stimuli are less likely to be selected for further processing when observers perform a perceptually demanding task (e.g., Lavie, 1995). Indeed, observers are less likely to notice salient objects under conditions of high perceptual load (Cartwright-Finch & Lavie, 2007). In the present study, participants tracked a set of four moving objects, which is thought to be a relatively demanding task (Cavanagh & Alvarez, 2005). However, although it is possible that perceptual load influenced noticing rates in the present study, previous work suggests that perceptual load does not modulate the effects of semantic relationships on attention (Belke et al., 2008) or awareness (Koivisto & Revonsuo, 2009). Thus, it is unlikely that the present findings were due to the perceptual demands of our task.

Another alternative explanation for the present findings is that properties of our stimuli may not have required participants to rely on category-level attentional sets. Because members of the same category are more perceptually similar than members of different categories, participants may have tracked objects based on their visual features rather than their semantic category. Thus, the present findings may have been due to the use of feature-based attentional sets. Although this possibility is difficult to rule out, Experiment 4 provides suggestive evidence against such an explanation. Specifically, because dogs and cats are more perceptually similar than monkeys and rabbits, participants should have been less likely to track these objects based on their visual features. A similar strategy was used by Most (2013), who had participants track perceptually similar images of letters and numbers. Although such strategies may reduce the use of feature-based attentional sets, future work should address the role of visual similarity in the present findings.

In summary, we found no evidence that associative relationships influence visual awareness. Although participants were more likely to notice objects that were visually salient or belonged to the same category as their current attentional set, they were no more likely to notice objects that shared a semantic association with this attentional set. These findings not only clarify the role of semantic relationships in visual awareness, but also have consequences for many real-world activities. For example, a driver who is monitoring the road for cars may be more likely to notice an oncoming car than a pedestrian who is crossing the road. Thus, although categorical relationships play an important role in our visual awareness of objects, this effect does not extend to associative relationships among objects.

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Notes

1. In the semantic memory literature, categorical relationships are sometimes referred to as *taxonomic relationships*, while associative relationships are sometimes referred to as *thematic relationships* (e.g., Estes, Golonka, & Jones, 2011). Here, we use the more common terms for these relationships.
2. Using a more conservative noticing criterion (e.g., if participants answered all questions correctly) did not change the pattern of results in any of our experiments.

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