Selective Attention in Inattentional Blindness: Selection is Specific but Suppression is Not
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When we selectively attend to one set of objects and ignore another, we often fail to notice unexpected events. The likelihood of noticing varies depending on the similarity of an unexpected object to other items in the display, a process thought to be controlled by the attention set that we create for the attended and ignored objects. It remains unclear, though, how attention sets are formed and structured. Do they enhance features of attended objects ("white") and suppress features of ignored objects ("black"), or do they distinguish objects based on relations or categories ("darker" versus "lighter," or "dark objects" versus "light objects")? In previous work, these explanations are confounded; the objects would be partitioned into the same groups regardless the structure of the attention set. In the present three experiments, the attended or ignored set of objects was a constant color while the other set was variable. When people attended white and ignored a multicolored set of objects (Experiment 1), novel colors were suppressed just as much as display colors, suggesting nonselective filtering of nonwhite objects. When the color of one set of objects varied across displays but was constant within them (Experiments 2 and 3), we again found as much suppression for task-irrelevant and novel colors as for actively ignored ones. Whenever people ignored a set of objects that varied in color, they suppressed unexpected objects that matched the ignored colors and that differed from the actively ignored items on the critical trial. In contrast, when people attended a varying set, noticing was enhanced only for unexpected objects that matched the currently attended color. In this task, attentional filtering is category-based and did not depend on the features of the individual objects.

Keywords: attention; attention sets; inattentional blindness; attentional filtering; selective attention

Inattentional blindness is a remarkable illustration of our ability to focus attention exclusively on relevant information and filter distracting information from awareness. Sustained inattentional blindness tasks induce these attentional demands by tasking subjects with tracking one set of moving objects and ignoring the rest. Subjects in this state are often oblivious to unexpected stimuli, even strange ones that remain in view for seconds at a time (Neisser & Becklen, 1975; Simons & Chabris, 1999).

Our likelihood of noticing an unexpected object is heavily influenced by its similarity to other objects in the display. If we attend to objects based on color, we typically notice objects that match the attended color and miss those that match the ignored color (Most, Simons, Scholl, Jimenez, Clifford, & Chabris, 2001). These similarity effects occur for other features, such as shape, and they are flexible: When subjects attended to black circles and squares and ignored white ones, they noticed a black circle or square much more often than a white circle or square. When they viewed the same display but attended on the basis of shape instead (black and white circles versus black and white squares), circles of either luminance were noticed more often than squares (Most, Scholl, Clifford, & Simons, 2005). What seems to matter most to noticing is the unexpected object's similarity along the critical dimension that defines the attention set. Differences in irrelevant feature dimensions have less impact on noticing.

Such similarity effects have been observed for many feature dimensions, and they are thought to result from the attention sets subjects form during the task (Most et al., 2005). There is little agreement, however, in how these attention sets are structured or what aspects of similarity drive noticing. These attention sets might be entirely feature-based: We enhance features matching the attended set, drawing in objects that share those features and suppressing the distractor features. Consistent with this idea, when subjects attend to objects of one color and ignore two other sets of colorful objects—one nearer to the attended set in color space, and one much farther away—unexpected objects with colors similar to the attended set in color space are more likely to be noticed and those with colors close to the ignored ones are missed (Drew & Stothart, 2016).
Alternatively, attention sets might operate not on the specific features of the attended and ignored items, but in a more categorical way. Rather than enhancing “white” and suppressing “black,” the attention set might enhance “lighter” and suppresses “darker.” When display objects are red-orange and yellow-orange, and subjects are instructed to attend to the “redder” set, they unsurprisingly notice unexpected red-orange objects (Goldstein & Beck, 2016). However, they also notice extreme examples of the relation (red when attending to “redder” or yellow when attending to ‘yellower’) just as often as exact color matches. Although red is a better fit for the “redder” category, it also deviates more from the ignored, yellow-orange objects. Consequently, it is unclear whether the high rates of noticing result from greater similarity to the attended category or greater dissimilarity from the ignored one.

Attention sets might even operate at a semantic level. People are more likely to notice an unexpected block-face ‘E’ than a block-face ‘3’ when attending to letters and ignoring numbers, but they notice the 3 more often when attending to numbers and ignoring letters (Most, 2013). These two objects are nearly identical in their low-level features, but noticing rates differed based on whether they matched the attended and ignored semantic categories.

Each of these selection mechanisms may contribute to inattentional blindness, but few extant studies distinguish among them. Almost all inattentional blindness displays use two sets of objects that are homogenous with respect to the critical feature, dimension, or category. If objects are differentiated on color, subjects typically only have to attend white and ignore black. Yet, black and white objects will end up in the same groups if they are separated on absolute color value, luminance, relationships like “lighter” and “darker,” or broad categories like “light things” and “dark things.” Similarly, unexpected objects that vary along the same critical feature dimension will fall into one category or the other regardless of what truly determines “similarity”—dark gray is close to black relationally, in terms of its RGB value, its luminance, and its broader category, for example—making it difficult to determine what is driving the similarity relationship.

This redundancy can also undermine conclusions about similarity—even when subjects must ignore two separate colors while attending one (e.g., Drew & Stothart, 2016), they could segment the objects not based on the actual color value, but according to “bright colors” and “dark colors,” or “hot” and “cold” colors. Red objects and red-orange objects are both “redder” than yellow-orange objects, but also feature-similar to each other and dissimilar from the ignored objects (Goldstein & Beck, 2016). To determine which aspect of similarity drives the effects of attention sets on noticing, an experiment must isolate each possible mechanism, eliminating other ways to parse the display.

To remove this redundancy, we employed stimuli that are not easily separable along a single dimension but that could be distinguished either by individuating all of the features of the objects or by grouping them into coarse categories. This approach allows us to separate the contributions of feature similarity and category similarity on noticing rates for unexpected objects.

**Experiment 1**

In order to examine how attention sets are formed, we used two sets of objects in Experiment 1. Subjects performed a multiple object tracking task in which they counted bounces for one set of objects in the display while disregarding the bounces of the other set. One set consisted of four white shapes and the other consisted of four colorful shapes (black, red, yellow, and purple, with each color used once). These were chosen to prevent use of a single feature distinction to segment attended from ignored items (e.g., “white and black” or “light and dark”). To separate the objects, either subjects must track each object’s unique color (the “feature-based” hypothesis) or the objects must be sorted into coarser groups, such as “white” and “nonwhite” (the “category-based” hypothesis).

To determine which selection method people use, we can examine noticing rates for a unexpected green object that shares the category (“color”) or “nonwhite”) but not the specific features (black, red, yellow, or purple) of that set. When people attend to the colorful shapes and ignore white, an unexpected green object should be noticed at high rates regardless of whether selection operates on categories of features. If selection is feature-based, a green object should be noticed because it is unique and salient. If selection is category-based, a green object should be noticed because it matches the category (“nonwhite”) of the attended set. In both cases, green differs from the ignored shapes, and suppression of ignored shapes contributes to the likelihood of noticing (Most et al., 2001).

The informative case is when subjects are ignoring the colorful shapes. If selection is feature-based, then people should be ignoring “red, purple, black, and yellow.” Green differs from these colors, so it should escape suppression and be noticed at high rates. Alternatively, if selection is category-based and people are ignoring “nonwhite” shapes, then green falls within the suppressed category and it too should be suppressed (see Figure 1, Panel B).

**Methods**

Methods, procedures, target sample size, exclusion rules, stimuli, experimental code, and analysis scripts were preregistered sequentially, with each experiment preregistered before we started data collection for that experiment (https://osf.io/7pz35/). Data were analyzed using R (R Core Team, 2015) and are available on OSF. We report all data exclusions, measures, and manipulations here and in the preregistration (Simmons, Nelson, & Simonsohn, 2011).

**Subjects.** We aimed to collect usable data from 100 subjects in each of 6 conditions after exclusions (total target n = 600). Subjects were workers on Amazon Mechanical Turk who had at least 95% approval rates for their previously submitted HITs. We checked worker IDs against a database of prior subjects using TurkGate (Goldin & Darlow, 2013), and anyone who had previously participated in an inattentional blindness experiment from our laboratory or the laboratory of our collaborators...
was informed that they were not eligible for this HIT and were excluded prior to participating.

The need for signed consent was waived by the Institutional Review Board at the University of Illinois due to the low-risk nature of the experiment. Prior to the experiment, subjects were shown an information screen that provided experimenter and IRB contact information. It explained that their responses would be anonymous, described how their data would be used, and noted that their participation was voluntary.

Prior to analysis, we excluded subjects who skipped any questions during the experiment, miscounted in

Figure 1: Trial sequence, predictions, and results for Experiment 1. A. A schematic of the objects in each trial. All four colors appeared on each trial alongside the white objects. Subjects attended either to white or nonwhite shapes. The unexpected object was a randomly chosen shape and could be white, one of the display colors (red, black, purple, or yellow, chosen at random), or a new color (green). B. If objects are sorted into attention sets on the basis of their features (the “feature-based” hypothesis), then a novel object should stand out in the display when ignoring colors. Conversely, if the objects are separated on the basis of categories (the “category-based” hypothesis), a nonwhite novel object should be categorized into the same set as the other nonwhite objects in the display. C. Noticing rates for unexpected objects when attending colors (bottom) and ignoring colors (top); error bars represent 95% bootstrapped confidence intervals. Unexpected objects that matched a display color were collapsed into a single group, represented by the purple circle. Novel green objects were noticed at virtually identical rates to an unexpected object that matched another color in the display when subjects ignored colors, suggesting a category-based attention set. All plots were generated with the ggplot2 package for R (Wickham, 2009).
the tracking task by more than 50% in either direction on more than one trial, reported being younger than 18, reported experiencing any issues with the display or playback of the experiment, reported needing vision correction but not wearing it during the experiment, reported any form of color blindness, or misidentified the number in Ishihara Plate 9 (Ishihara, 1990). Based on prior studies using similar exclusion rules and sampling from the same online population, we anticipated the need to exclude 40% of the subjects who completed the task.

Subjects were automatically recruited in batches of up to nine, with random assignment to the six conditions, until at least 1000 had completed the experiment, at which point no further batches were posted. In total, we recruited 1001 subjects. Subjects received $0.10 upon completing the experiment.

**Materials and procedure.** A demonstration of the experiment, identical to the one subjects completed (but without any data collection), can be found at http://simonslab.com/mot/set_demo.html.

The experiment was coded in Javascript, and was modeled on prior online sustained inattentional blindness tasks (Cary Stothart, personal communication, October 9, 2015; e.g., Drew & Stothart, 2016). At the start of the experiment, instruction screens informed subjects that they would see two sets of objects—a group of white shapes, and a group of nonwhite shapes—bounce around inside a blue rectangle. They were told to count how many times either the white or nonwhite shapes bounced against the edges of the rectangle, and to disregard the bounces of the other group, all while keeping their eyes focused on a small blue fixation square centered in the window.

Both sets of objects consisted of a square (44 x 44 pixels), a diamond (identical to the square, rotated 45 degrees), a triangle (50 pixel base, 50 pixel height), and a circle (22 pixel radius). For one set, all four shapes were white (#FFFFFF). For the other set, each shape was randomly assigned (without replacement) to be red (#E41A1A), yellow (#EBF212), purple (#6E2A45), or black (#000000) at the start of the experiment (see Figure 1, Panel A).

On each trial, these eight objects moved around inside the blue (#58ACFA) frame (666 x 546 pixels) for 17 seconds. Each object moved independently with a velocity that could vary between 54 and 108 pixels per second, reversing direction when it came into contact with an edge of the frame. Objects occluded each other when they crossed paths, but always remained behind the fixation square (11 x 11 pixels, #0000FF). On average, the set of four objects bounced a total of 28.6 times (SD 2.1). After the trial ended, subjects were instructed to enter their bounce counts in a text box that restricted their response to integers between 0 and 99.

Subjects completed two non-critical trials in which they counted bounces and entered their responses afterward. On the third, critical trial, an unexpected object entered the display from the right edge after 5 seconds, moved horizontally along the midline from right to left, passed behind the fixation cross, and exited on the left edge of the rectangle 6750 ms after it first appeared. This object was randomly selected to be one of the four shapes in the display, and could be either white, one of the non-white colors (red, black, purple, or yellow), or green (#1B7E39).

After the trial ended, subjects entered their count as usual, but then were asked to report whether they had noticed ‘anything extra on the last trial that did not appear on the previous trials’ (‘yes’ or ‘no’). Regardless of their response, they were asked about the color (‘black,’ ‘yellow,’ ‘orange,’ ‘red,’ ‘green,’ ‘blue,’ ‘purple,’ ‘white,’ or ‘none of these’) and shape (‘square,’ ‘cross,’ ‘circle,’ ‘triangle,’ ‘diamond,’ or ‘none of these’) of the additional object.

Next, subjects reported their age, gender, country of residence, use of vision correction, status of their color vision, identification of Ishihara Plate 9, whether they encountered any issues with the display of the experiment, and whether they had any previous exposure to inattentional blindness tasks. After completing these questions, subjects received a completion code to enter on Mechanical Turk to receive payment.

**Results and Discussion**

Using our preregistered exclusion criteria, we excluded data from 448 subjects (44.8% of our sample), leaving 553 in the final analysis (see Table 1 for the number of subjects assigned to each condition). According to our preregistered criteria, subjects were counted as having noticed the unexpected object if they reported noticing an extra object on the critical trial and correctly reported its shape, color, or both.

Regardless of whether the category-based hypothesis or the feature-based hypothesis is correct, white unexpected objects should be noticed more often when attending to white than when ignoring white, and colored unexpected objects that match colors already in the display should be noticed more when attending to colors than when attending to white. As predicted, the difference in noticing rates between the attend-white and attend-non-white conditions was large and positive for white unexpected objects (68.9% versus 0.9% for a difference of 68%, 95% bootstrapped CI: [58.9, 75]) and equally large and negative for colored unexpected objects (2.7% versus 70.7% for a difference of −68%, 95% bootstrapped CI: [−72.2, −60.6]; see Figure 1, Panel C).

The feature-based hypothesis makes a different prediction about the difference in noticing rates for a new, green object than does the category-based hypothesis. If the individual features of each object are used to form the attention set, then a green object should be noticed at a high rate regardless of whether people are attending to white or colored shapes (no difference in noticing between conditions; Figure 1, Panel B, “Feature-based”). Conversely, if attention sets are category-based, then the green object should be grouped into the category-based attention set for the non-white objects; it should be noticed rarely when attending white and ignoring colors, but frequently when attending colors and ignoring white (a large negative difference; Figure 1, Panel B, “Category based”). The results match the predictions of the category-based model of attention sets: Green unexpected objects
were noticed rarely when ignoring colors, but noticed frequently when attending them (4.1% versus 77.1% for a difference of –73%, 95% bootstrapped CI: [–77%, –66%]; see Figure 1, Panel C).

Apparently, the attention set formed in this task is category-based rather than feature-based. People appear to suppress anything matching the category “colored” or “non-white” rather than specifically suppressing black, red, yellow, and purple. Such category-based attention sets have been shown before with semantic categories (Most, 2013), but this experiment suggests that even simple visual stimuli are coarsely categorized when forming attention sets.

Experiment 2
The category-based suppression observed in Experiment 1 might not apply to all cases of inattentional blindness. Perhaps people form attention sets flexibly, using category-based selection when conditions allow it and feature-based selection in other contexts. Asking people to ignore or attend to four colors at once may have taxed working memory, so forming a category-based attention set to cover all non-white objects was the most efficient way to perform the task. If that load were reduced, would people still form a category-based attention set? In other tasks, reducing perceptual load increases awareness of irrelevant stimuli (Cartwright-Finch & Lavie, 2007), and the same might hold for sustained inattentional blindness.

In Experiment 2, we reduced the load on working memory while ensuring that the absolute color of the non-white stimuli remained irrelevant. On each trial, rather than presenting four different colors simultaneously, the non-white set was composed of just one color. That color changed on each trial (e.g., white versus purple, then white versus red, then white versus yellow). On each trial, then, subjects still attend to white or color, but they have minimal memory load—they can ignore the category of “color,” or selectively ignore the single color presented on the current trial.

If working memory demands alone drove the pattern of results observed in Experiment 1, then when people attend white and ignore colors, we should only observe suppression for an unexpected object that matches the current color on that trial; previous colors and novel colors (i.e., green) should escape suppression because they differ from the ignored color (Figure 2, Panel B, “Working Memory”). If attention sets are category-based even when the memory load is minimal, then any colorful unexpected object should be suppressed, even when it differs from the color on that trial (Figure 2, Panel B, “Variability”).

Methods
A version of the experiment that does not collect data but is otherwise identical to the one used in the experiment can be found here: http://simonslab.com/mot/color_demo.html. Except where noted, the methods were identical to those of Experiment 1. We recruited 1002 subjects through Mechanical Turk, again with the goal of 100 subjects per condition after exclusions.

The non-white objects on each trial all shared a single color, but the color was different on each trial (red, yellow, and purple, ordered randomly for each participant; see Figure 2, Panel A). The unexpected object was a randomly selected shape, and could be either one of the colors used

<table>
<thead>
<tr>
<th>Experiment 1</th>
<th>Unexpected Object Category</th>
<th>White</th>
<th>Color</th>
<th>New</th>
<th>Total</th>
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<tbody>
<tr>
<td></td>
<td>Attend White</td>
<td>90</td>
<td>75</td>
<td>98</td>
<td>263</td>
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<tr>
<td></td>
<td>Attend Nonwhite</td>
<td>108</td>
<td>99</td>
<td>83</td>
<td>290</td>
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<tr>
<td>Total</td>
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<th>Unexpected Object Category</th>
<th>Critical Trial Color</th>
<th>Previous Trial Color</th>
<th>New Color</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Attend White</td>
<td>92</td>
<td>92</td>
<td>91</td>
<td>275</td>
</tr>
<tr>
<td></td>
<td>Attend Nonwhite</td>
<td>87</td>
<td>96</td>
<td>77</td>
<td>260</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>179</td>
<td>188</td>
<td>168</td>
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<tr>
<th>Experiment 3</th>
<th>Unexpected Object Category</th>
<th>Critical Trial Color</th>
<th>Previous Trial Color</th>
<th>New Color</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Attend Constant</td>
<td>65</td>
<td>56</td>
<td>59</td>
<td>180</td>
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<tr>
<td></td>
<td>Attend Variable</td>
<td>66</td>
<td>73</td>
<td>54</td>
<td>193</td>
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<tr>
<td>Total</td>
<td></td>
<td>131</td>
<td>129</td>
<td>113</td>
<td>373</td>
</tr>
</tbody>
</table>
for the display shapes in the non-critical trials, the same color as the non-white objects on the critical trial, or a new color (green). The same response options were available for the appearance of the unexpected object except “orange,” which was dropped from the possible colors.

**Results and Discussion**

After applying the same exclusion criteria as in Experiment 1 (eliminating data from 467 subjects—46.6% of our sample), our analyses included 535 subjects (see Table 1 for a breakdown of condition assignment).
Consistent with the results of Experiment 1 and inconsistent with the memory load account, all colors were noticed less often when attending white and ignoring a single color than when attending to a single color and ignoring white. Even unexpected objects with colors that were unique in the display on the critical trial were missed. The difference in noticing an unexpected colored object when ignoring a color versus when attending to a color was negative in all cases (unexpected objects that matched a color encountered on an earlier trial: 7.6% versus 41.7% for a difference of –34.1%, 95% bootstrapped CI: [–38, –29.1]; unexpected objects that matched the current color: 9.8% versus 67.8% for a difference of –58%, 95% bootstrapped CI: [–60.8, –53.1]; unexpected objects in a novel color: 17.6% versus 49.4% for a difference of –31.8%, 95% bootstrapped CI: [–35.6, –28]; see Figure 2, Panel C).

Despite having to attend to and ignore just one color on each trial, subjects formed an attention set for the entire category of “color,” effectively suppressing detection of unexpected colors that were unique to the display on that trial. Apparently, the selective suppression of objects from the broad category of “color” in Experiment 1 was not because working memory was overloaded, but because having to ignore a variable feature led people to establish a category-based filter.

When people attended to that variable feature, however, the pattern was not as consistent; an unexpected object that matched the currently-attended color was noticed more often than either a previously-attended color or a novel color. While people effectively suppressed a variable category, they seemed less likely to enhance one.

Experiment 3

The results of Experiment 2 present an intriguing possibility: When people ignore a varying set of objects and attend to something constant, any object that differs from the attended one is suppressed. Neither novelty nor task irrelevance rescues these objects. Conversely, when people attend to a varying set of objects, everything is noticed more often, although even novel objects are still noticed less often than objects that perfectly match what the currently attended feature.

In Experiment 2, the constancy versus variability manipulation was confounded with pre-existing natural categories: “chromatic” and “achromatic” objects. The varying objects were also the colorful ones, and the constant objects were always white. Consequently, the different pattern of noticing when the attended and ignored items are variable might be explained by a difference in how well people can ignore or attend to “chromatic” objects as a category. If so, the pattern in Experiment 2 would be consistent with a similarity effect: chromatic objects go unnoticed when ignored but are detected when attended.

To test whether natural chromaticity categories drove the effect in Experiment 2, we replaced white objects with pink ones so that there were no “achromatic” objects, and let the color of the constant objects be a randomly selected color for each subject instead of fixed for all subjects. If the results of Experiment 2 were due to the use of “chromatic” as a category, then we should not replicate the pattern in Experiment 3 (Figure 3, Panel B, “Chromaticity”). However, if the results of Experiment 2 were due to the ease with which people enhance or suppress heterogeneous categories, then Experiment 3 should replicate the pattern observed in Experiment 2; noticing rates for all colors of unexpected object should be lower when ignoring the varying color objects than when ignoring the constantly colored one (Figure 3, Panel B, “Replicate Ex. 2”).

Methods

A demo version of the experiment may be found here: http://simonslab.com/mot/scramble_demo.html. Except where noted, methods are identical to those of Experiments 1 and 2. Because the effects we were aiming to replicate from Experiment 2 were large, for this experiment we aimed to recruit 50 per cell for a total of 300 after exclusions. We recruited 609 subjects through Mechanical Turk.

The experiment procedure was identical to Experiment 2, except that the white objects were replaced with pink ones (#FFCCBF). Rather than a single constant color (white in Experiments 1 and 2), each subject was randomly assigned a “constant” color that appeared as one of the sets on every trial. The other set of objects all shared the same color, selected from the non-constant ones for that participant (see Figure 3, Panel A). Subjects were assigned to attend either to the constant color or to the color that changed from trial to trial. The unexpected object could be entirely novel (green), match the non-constant color from a previous trial, or match the non-constant color on the critical trial.

Results and Discussion

234 subjects were excluded prior to analysis (38% of our sample) according to the same exclusion criteria used in Experiments 1 and 2, leaving 373 subjects (see Table 1 for the numbers assigned to each condition).

Unlike in previous experiments, here subjects could not distinguish the sets of objects based merely on the presence or absence of color; all objects were chromatic, and there was no systematic relationship between the colors of the objects. The only way to separate the objects without using individual features is to use categories such as “the constant color” (e.g., “yellow”) and “the other colors” (e.g., “not yellow”).

Despite the absence of a pre-existing category, Experiment 3 replicated the results of Experiment 2 when subjects ignored the varying color (see Figure 3, Panel C). In all conditions, the difference between noticing rates when ignoring the varying colors versus attending to them was negative; subjects who ignored varying colors were always more likely to miss a colored unexpected object (unexpected objects that matched a varying color from a previous trial, 10.7% versus 26% for a difference of –15.3%, 95% CI: [–17.8, –12.5]; an unexpected object that matched the current color from the variable set, 4.6% versus 74.2% for a difference of –69.6%, 95% CI: [–74.1, 63.6]; an unexpected object in a novel color, 11.9% versus 31.5% for a difference of –19.6%, 95% CI: [–24, 15.1]). It appears that
people can establish attention sets solely on the basis of constancy and variability.

One interesting pattern, present in Experiment 2, was amplified in Experiment 3. When subjects were attending to the variable colors, they noticed all unexpected objects more often than when ignoring the variable colors. However, whereas the color they were attending was noticed at fairly high rates (74%), the other colors were noticed considerably less often (26% for the previously attended colors and 32% for the new color). The effects...
of suppression were consistent across experiments: When people ignore varying colors, whether they vary within a trial (Experiment 1) or across trials (Experiments 2 and 3), they suppress all non-attended colors. In contrast, Experiments 2 and 3 revealed that when people attend to varying colors, noticing is only enhanced for the currently attended color. There is no increase in noticing for previously attended colors or for novel colors.

**General Discussion**

Across three experiments, people formed attention sets that suppressed variations in color, leading to reduced noticing of unexpected objects of any color, irrespective of task-relevance or novelty. When one set of objects was constant and the other was heterogeneous within a trial or homogenous but variable across trials, subjects established an attention set that suppressed detection of other colorful shapes, even unique ones. Although the suppressive effect of ignoring a set of shapes seems to be broad in scope, the enhancement of attended features appears to be narrower. People tend to notice unexpected objects that match the current attended feature more than unique colors or colors that match previously attended features.

In Experiment 1 people either attended white and ignored a set of colorful shapes, or vice-versa. The two models for attention sets—category-based and feature-based—make different predictions for noticing of an unexpected, novelly colored object when attending to white objects and ignoring colored objects. Consistent with the category-based selection model, noticing of a unique green shape was just as suppressed as noticing of other colors in the display, despite being featurally distinct from the ignored set.

Experiment 2 confirmed that the broad suppression was due to variability of the color rather than to working memory load: Even when the colors within a trial were homogenous, variation in the color across trials affected the attention set in a category-based way. When subjects ignored the varying color set they missed not only unexpected objects that matched the color on the critical trial, but also colors they had ignored before and a completely novel color not yet encountered in the display. Every color was filtered, even if it was no longer task relevant or had never been encountered before.

In contrast, when attending to the varying color and ignoring white objects, an unexpected object matching the color on that trial was noticed more often than unexpected objects matching previously encountered colors or a novel color. These differences increased in Experiment 3, when we replaced white with pink and designated one color at random to remain fixed throughout the experiment. Experiment 3 also confirmed that selective ignoring operates in a category-based way in the face of variability, even when eliminating a possible simple feature dimension (chromaticity) as a way to establish an attention set.

This asymmetry in effects for selective attention and selective ignoring is suggestive. In previous inattentive blindness work, the pattern of results often reverses when the attended and ignored items are swapped. For example, when you attend black and ignore white, you see black often but rarely catch white; when you ignore black and attend white, the data reverse (Most et al., 2001). In this case, however, we observe two different data patterns when subjects attend to variability versus ignore it. When subjects ignore variability, people apparently suppress ignored objects in a category-based way, suppressing objects with features that are not part of the current display. In contrast, when attending to variability, selection appears to be more feature-based. Unexpected objects that perfectly match the attended ones are noticed at a high rate, but other objects are noticed less frequently.

**Constraints on Generality**

All three experiments establishing filtering using color as the critical feature. Given that similarity effects in inattentional blindness research have been studied with a wide variety of stimuli (Simons and Chabris, 1999; Most et al., 2001; Most et al., 2005), we expect this effect to generalize to other kinds of simple objects, provided that a “constant” category is pitted against a “variable” category. If the objects must be separated along a single feature dimension, such as shape, luminance, or color, and one set contains members that are heterogeneous with respect to this critical feature, we would expect to observe the same general pattern (broad suppression when ignoring the variable group, and narrow selection when attending to it). The effects may even be stronger the more difficult it is to segment the objects, based on how noticing rates changed between Experiments 2 and 3; white was apparently easier to ignore than another color, so noticing rates were higher when ignoring white than when ignoring a randomly selected,unchanging color. However, these results might not generalize to more complex objects or richer stimulus categories that vary along more than one simple feature.

Although it is possible that the pattern we observed would vary with different task instructions, we expect that they would be robust to such variations given that people tend to partition sets of objects in simplest way they can, even when they are instructed to use a different feature; for example, when given white diamonds and black squares and told to attend squares and ignore diamonds, noticing of unexpected objects suggests that people use luminance instead (Aimola Davies, Waterman, White, & Davies, 2013).

We used a relatively diverse online sample, and given that inattentional blindness studies have shown effects of similarity in both online studies and in laboratory settings and with subjects of varying ages, we expect our pattern of results would generalize to any population of adult subjects who meet our inclusion criteria (although absolute noticing levels might vary across samples).

**Conclusion**

Previous studies of the contribution of attention sets to inattentional blindness appeared to provide evidence for sets based on features, relations, and even semantic categories. However, these options are indistinguishable in most previous work because the stimuli in the display could be distinguished in multiple ways. For example,
black and white shapes differ in absolute RGB value, relative luminance, color class, and so on. Unexpected objects also fall nearer to one of the sets of objects according to multiple criteria: a “darker” object is also closer to black in RGB space, meaning attention sets based on relations and features make the predictions for noticing rates.

In our experiments, the display objects were heterogeneous with respect to color, the critical feature. While one set of objects all shared the same color, the other set varied, either within trials or across them. With variation in color, the different types of attention sets made different predictions for the patterns of noticing for unexpected objects; a feature-based approach predicted a pattern of noticing completely distinct from that predicted by a coarser, category-based approach.

Across three studies, subjects formed broad, category-level attention sets that seem consistent with two categories: “attended objects” and “everything else.” The “everything else” category contains not just distractors that need to be immediately ignored, but also stimuli that have been encountered before and even completely novel stimuli. Indeed, the only type of unexpected object that was consistently noticed at a high rate was one that exactly matched the currently attended objects. The objects we must immediately contend with gain access to our awareness; all others, old and new, are suppressed.

Data Accessibility Statement
The pre-registration documentation for each experiment and all materials, including data for all subjects, are available at https://osf.io/7pz35/.

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Competing Interests
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KW and DJS jointly planned and designed the experiments. KW coded the experiments and analysis scripts, oversaw data collection, and conducted the analysis, and drafted the manuscript. Both authors critically edited the manuscript and approved the final version for publication.

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