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The costs (or benefits) associated with attended objects do little to
influence inattention blindness

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Abstract

We sometimes fail to notice unexpected objects or events when our attention is directed elsewhere, a phenomenon called inattentional blindness. We explored whether unexpected objects that shared the color of consequential objects would be noticed more often. In three pre-registered experiments, participants played a custom video game in which they avoided both low- and high-cost missiles (Experiment 1 and 2) or tried to hit rewarding missiles while avoiding costly ones (Experiment 3). After participants had played the game for about 8 minutes, an unexpected object moved across the screen. Although participants selectively avoided more costly missiles when playing, they were no more likely to notice an unexpected object when its color was associated with greater costs. Apparently, people are no more likely to notice unexpected objects that are associated with negative consequences. Future research should examine whether objects that are themselves consequential are noticed more frequently.

Introduction

In 2014, home security camera footage captured a couple walking out of their home as a bear approached them, stopped, and then stood approximately 10 feet away, directly in the husband's line of sight. Neither noticed it. Fortunately, the couple survived mostly unscathed (Huffington Post, 2014), but this and other real-world cases of inattentional blindness (e.g., looked-but-failed-to-see automobile crashes), can have consequences. For example, a Boston police officer was convicted of perjury and obstruction of justice for claiming not to have witnessed a beating when he plausibly could have experienced inattentional blindness (Lehr, 2009).

Inattentional blindness—the failure to notice unexpected objects or events when attention is otherwise occupied—has been observed in a wide range of contexts: during simple computer tasks (e.g., Mack & Rock, 1998), in videos (e.g., Simons & Chabris, 1999), while driving in a simulator (Most & Astur, 2007; Strayer, Drews, & Johnston, 2003), during real-world experiments (Chabris, Weinberger, Fontaine, & Simons, 2011), and in observational studies of typical behavior (Hyman et al., 2010). Noticing rates for unexpected objects vary with the age of the observer (Graham & Burke, 2011; Stothart, Boot, & Simons, 2015; Stothart et al., 2016), the salience of the object, and how well the object matches the observer's goals and attention set (Most, Scholl, Clifford, & Simons, 2005). Yet, anecdotes like the unexpected bear and looked-but-failed-to-see crashes suggest that even objects that pose a direct threat or risk to people might go unnoticed. Despite this suggestive evidence, few studies have explored whether the risk or threat of an unexpected object increases the likelihood of noticing it.

Several studies have examined whether evolutionarily-relevant threats (e.g., spiders and snakes) are noticed more than non-threatening objects or threatening objects that were not

evolutionarily-relevant (e.g., guns and needles; Wiemer, Gerdes, & Pauli, 2013; New & German, 2015; Calvillo & Hawkins, 2016). Some found higher noticing rates for threatening objects (New & German, 2015), but others did not (Wiemer, Gerdes, & Pauli, 2013; Calvillo & Hawkins, 2016). Yet, in all cases, the unexpected object was a picture of a threatening or non-threatening object, and participants knew that nothing about the displays they viewed could affect them.

Although a laboratory study cannot put participants in physical danger from an unexpected object, they can vary whether an unexpected object has consequences for task performance. However, making the unexpected object task-relevant potentially changes the nature of the primary task. So, we varied whether the features of the unexpected object matched those of task-relevant objects. Specifically, we varied whether the color of the unexpected object matched that of other objects in the display that themselves varied in their consequences for task performance.

In three pre-registered experiments, we examined the role of such associated consequences on inattentional blindness with a custom-designed video game in which participants tried to dodge enemy missiles of varying cost or dodge enemy missiles while hitting “friendly” ones. On a critical trial, we introduced an unexpected object that matched the color of the low cost, high cost, or reward missiles. This design allowed us to measure whether unexpected objects whose color matched more costly objects would be noticed more frequently. Unlike earlier studies that compared noticing rates for threatening objects to non-threatening ones, our unexpected objects varied only in color. With appropriate counterbalancing, the inherent features of the stimuli themselves cannot explain overall differences in noticing rates.

In Experiments 1 and 2, the game featured enemy missiles that varied in their costs. We examined whether people were more likely to notice an unexpected object if its color matched

the more costly missiles. In Experiment 3, the game featured both enemy and friendly missiles to determine whether people would be more likely to notice unexpected objects associated with cost than ones associated with reward. All three experiments also included a baseline “neutral” condition in which the unexpected object matched neither the enemy nor friendly missiles. Finally, we explored whether the spatial proximity of the unexpected object interacted with consequentialness: The unexpected object appeared outside of the primary game area (Experiments 1 and 3) or within the game area (Experiment 2).

Method

The method, procedure, and analysis plan for each experiment were pre-registered on the Open Science Framework (<https://osf.io/4b5ns/>), and all materials, datasets, and analyses for all experiments can be found there as well. The first author programmed the video game (in JavaScript) and also implemented the surveys (in HTML). The order of the tasks and surveys were controlled using PHP. Except where noted, all three experiments used identical methods. All experiments were approved by the Institutional Review Board at Florida State University.

Video Game

In the game, participants moved their rectangle up and down to dodge or hit missiles shot by other colored rectangles (see Figure 1 for a screenshot and Table 1 for characteristics of the objects). Those rectangles were confined to the right 22% of the display where they moved around randomly (changing direction unpredictably every 1-4 seconds), bouncing off of the display’s edges or the invisible boundary delineating the right 22% portion. Each of the rectangles fired missiles approximately once per second. The color of each missile matched the color of the rectangle that fired it, and they moved across the display from right to left. If the

player collided with an enemy missile, their score decreased. If they hit a friendly one, their score increased.

In Experiments 1 and 2, the game featured only enemies. Half of the enemies fired high-cost missiles (-20 points) and half shot low-cost missiles (-2 points). Participants gained 2 points for every second of game time that they avoided being hit by a missile. In Experiment 3, the game featured an equal number of enemies (-1 point) and friends (+1 point), and scores increased only by hitting friendly missiles.

The game lasted 8 minutes. Ten seconds before it ended, an unexpected object emerged from the bottom of the display, moved vertically, and exited at the top edge of the display. Horizontally, it either fell outside the attended game area (25px from the left edge; Experiments 1 and 3) or inside of it (300px from the left edge; Experiment 2). In all experiments, the unexpected object's color either was unrelated to the missiles or matched one of the two missile colors. The colors assigned to enemy or friendly missiles were counterbalanced across participants.

In addition to the friends and enemies, the game included additional white and black rectangles that had no relevance to the game. These were included to make the unexpected object less noticeable by reducing its salience in terms of onset, motion speed, and motion trajectory. After every second of game time, one of these additional rectangles appeared from the top or bottom of the display at a random location on the horizontal axis (other than those horizontal positions corresponding to the participant's rectangle or one of the enemies or friends) and moved vertically across the display, disappearing once it reached the opposite side.

Table 1. The characteristics of the objects in the game.

Object	Size (px)	Color	Speed (px/s)
Game Display	900 x 500	Gray	N/A
Participant's Rectangle	70 x 50	White	180
Missiles	8 (radius)	Yellow, Green, or Blue	Exp. 1 & 2: 240; Exp. 3: 360
Enemies and Friends	20 x 50	Yellow, Green, or Blue	60
Distractor Rectangles	20 x 50	White or Black	180
Unexpected Object	50 x 50	Yellow, Green, or Blue	180

Figure 1. Illustration of the video game. Both versions of the game can be played at

<http://www.cary-stothart.net/files/mean-rectangles.html> and <http://www.cary-stothart.net/files/mean-nice-rectangles.html>.

The highest score participants achieved was 882,

898, and 1120 for Experiments 1, 2, and 3, respectively.

Procedure

After playing the game, participants reported the color of the more costly missile (Experiments 1 & 2) or the rewarding missile (Experiment 3) to make sure that they understood

the task. They then answered forced-choice questions about the unexpected object: 1) “during the game, did you notice anything appear that was NOT a rectangle or circle?” 2) “if you did notice something new appear, was it moving?” 3) “if it was moving, what direction was it moving in?” 4) “if you did notice something, what color was it?” 5) “if you did notice something, what shape was it?” Participants were encouraged to guess if they were unsure. Participants then answered questions about the display (e.g., if there were any software glitches), their vision, and their demographics (see <https://osf.io/9qr7x/> for the full set of questions).

Participants were coded as having noticed the unexpected object if they reported seeing something other than a rectangle or circle and were also able to correctly report one of the unexpected object’s features. They were coded as having not followed instructions if they: (a) couldn’t remember the color of the more costly (Experiments 1 & 2) or rewarding missile (Experiment 3), (b) hit as many or more missiles associated with greater costs as ones associated with lesser or no costs.

Results

Participants

Participants were from the United States and were recruited and tested online using Amazon Mechanical Turk. In order to have 80% power to detect a 15% difference between conditions ($\alpha=.05$), we continuously collected data until we reached a minimum of 525 participants (after exclusions) in each experiment (175 per condition). We excluded participants based on a set of pre-registered criteria (Table 2) and continued collecting data from posted slots until we surpassed our minimum sample size. Consequently, the final sample sizes exceeded our minimum target (Experiment 1 $n=576$; Experiment 2 $n=595$; Experiment 3 $n=599$; see Table 3 for demographic information).

Table 2. The number and percentage of participants matching each exclusion criterion in each experiment. Note that participants could be excluded for multiple reasons (see our preregistration for a full description of the exclusion rules).

Exclusion Rule	Exp. 1	Exp. 2	Exp. 3	All
Previous participation in current study	33 3.99%	33 3.70%	33 3.94%	99 3.87%
Reported not having normal or corrected-to-normal vision	64 7.73%	57 6.39%	61 7.29%	182 7.12%
Failed the colorblindness test	24 2.90%	22 2.47%	13 1.55%	59 2.31%
Failed an attention test	41 4.95%	42 4.71%	44 5.26%	127 4.97%
Entered a nonsensical response for one of the open response questions or reported that the task did not work correctly	65 7.85%	38 4.26%	51 6.09%	154 6.02%
Failed to follow instructions	96 11.59%	109 12.22%	20 2.39%	225 8.80%
Participated in previous experiment	0 0%	100 11.21%	69 8.24%	169 6.61%
Total Tested	828	892	837	2557
Total Excluded	252	297	238	787

Table 3. Demographic information for each experiment.

Experiment	Female	Mean Age (SD)
Experiment 1	57%	33.83 (10.93)
Experiment 2	54%	32.25 (10.17)
Experiment 3	57%	32.89 (11.16)

Pre-Registered Analyses

Chi-Square tests assessed differences in noticing and t-tests assessed differences in task performance (Tables 5 and 6). All analyses were conducted in R version 3.1.2 (R Core Team, 2014), with Bayes Factors calculated using the BayesFactor package (version 0.9.12-2; Morey & Rouder, 2015), Chi-Squares calculated using the gmodels package (version 2.16.2; Warnes, Bolker, Lumley, & Johnson, 2015), and Cohen's *d* effect sizes calculated using the compute.es package (version 0.2-4; Del Re, 2013). The pre-registered analysis scripts are available at OSF (<https://osf.io/4b5ns/>).

As a manipulation check, we verified that people took the different missile costs into account when playing the game. In all experiments, participants hit at least twice as many missiles associated with lesser cost (or reward) than ones associated with greater cost (see Table 4).

Experiment 1 tested whether people would be more likely to notice an unexpected object if its color matched the more costly missile than if it matched the less costly one. Association with greater costs had little effect on noticing rates. Participants were numerically (although not significantly) *less* likely to notice the unexpected object when its color matched the higher cost missiles (9%). Performance on the task (low cost missile hits / high cost missile hits) also did not predict noticing, $B = 0.06$, $SE = 0.04$, $Odds\ Ratio = 1.06$, 95% CI [0.97, 1.16], $p = .205$.

In Experiment 1, the unexpected object appeared on the left side of the display. Participants were unlikely to devote attention to that region because missiles approached from the right, and any missile to the left of the player's rectangle could no longer affect them. Experiment 2 tested the same hypothesis as Experiment 1, but with an unexpected object that appeared among missiles that could affect the player. Consequently, it was in a region that likely

was attended. Once again, associated consequence had little effect on noticing rates. In this experiment, participants were numerically (but not significantly) more likely to notice the unexpected object when its color matched that of the more costly missiles (a 7% difference). Game performance again did not predict noticing, $B = 0.03$, $SE = 0.05$, $Odds\ Ratio = 1.03$, 95% CI [0.94, 1.15], $p = .525$.

Experiment 3 tested whether noticing rates would be greater for an unexpected object associated with cost than one associated with reward. As for Experiments 1 and 2, the associated consequences had little effect on noticing. Participants were somewhat less likely to notice an unexpected object when its color was associated with a cost than a reward (an 11% difference). Once again, noticing was not predicted by game performance, $B = .002$, $SE = 0.018$, $Odds\ Ratio = 1.002$, 95% CI [0.971, 1.044], $p = .893$.

All three experiments included a neutral condition to determine whether objects associated with a cost or reward would be noticed more than one associated with neither a cost nor a reward. In every experiment, though, more participants noticed the neutral unexpected object than the other types of unexpected objects. Note, though that the neutral object's color was unique in the display, so the greater noticing rates might have been due to greater salience.

Table 4. Missile hits as a function of missile consequence.

Condition	Mean # of Missile Hits (<i>SD</i>)		<i>d</i>	95% Confidence Interval	<i>p</i>	Bayes Factor
	Cost	Lesser Cost or Reward				
Experiment 1	67.69 (44.35)	140.94 (61.58)	1.36	[1.24, 1.49]	< .001	1.076971e+155
Experiment 2	68.81 (44.27)	143.55 (64.38)	1.35	[1.23, 1.48]	< .001	1.768899e+165
Experiment 3	143.43 (63.36)	553.33 (132.24)	3.95	[3.76, 4.15]	< .001	2.679392e+287

Table 5. The percentage of people noticing the unexpected object for each condition in each experiment.

Unexpected Object Color Matched...	% Noticing	95% Confidence Interval	<i>N</i>
Experiment 1			
More Costly Enemy	30%	[24%, 37%]	186
Less Costly Enemy	39%	[32%, 46%]	202
Neutral	62%	[55%, 69%]	188
Experiment 2			
More Costly Enemy	53%	[46%, 59%]	204
Less Costly Enemy	46%	[40%, 53%]	194
Neutral	70%	[63%, 76%]	197
Experiment 3			
Enemy	44%	[38%, 51%]	204
Friend	55%	[48%, 62%]	190
Neutral	78%	[71%, 83%]	205

Table 6. Differences between conditions in the percentage of participants who noticed the unexpected object.

Comparison	Noticing Difference	<i>OR</i>	95% Confidence Interval	<i>p</i>	Bayes Factor
Experiment 1					
More Costly vs. Less Costly	9%	1.50	[0.96, 2.34]	.061	1.45
More Costly vs. Neutral	32%	3.91	[2.49, 6.19]	< .001	88959741.00
Less Costly vs. Neutral	23%	2.61	[1.71, 4.03]	< .001	6922.45
More + Less Costly vs. Neutral	28%	3.15	[2.17, 4.62]	< .001	58991941.00
Experiment 2					
More Costly vs. Less Costly	7%	0.79	[0.52, 1.19]	.227	0.26
More Costly vs. Neutral	17%	2.07	[1.35, 3.19]	.001	57.16
Less Costly vs. Neutral	24%	2.63	[1.71, 4.08]	< .001	6134.57
More + Less Costly vs. Neutral	20%	2.33	[1.60, 3.41]	< .001	5963.01
Experiment 3					
Enemy vs. Friend	11%	1.56	[1.03, 2.38]	.027	1.44
Enemy vs. Neutral	34%	4.36	[2.79, 6.89]	< .001	5080370389
Friend vs. Neutral	23%	2.79	[1.77, 4.44]	< .001	7863.36
Enemy + Friend vs. Neutral	28%	3.52	[2.37, 5.29]	< .001	888195360

Discussion

In three experiments, participants played a video game in which differently colored objects varied in their consequences. Participants reliably used these different consequences when playing the game, but they were no more likely to notice an unexpected object when its color matched a high-cost object than when it matched a low-cost or rewarding one. The pattern held both when the object appeared within the attended region and outside of it.

Previous evidence for greater noticing of unexpected but threatening objects could have resulted from differences in the features/salience of the threatening and non-threatening stimuli. Those studies did not match the unexpected objects. In contrast, our experiments controlled for such differences by varying only the color of the unexpected object and its similarity to the other objects in the display. At least in this sort of sustained inattentional blindness task, the consequences associated with the unexpected object's color do not affect the likelihood of noticing it.

It may seem possible that our low noticing rates for the consequence-associated objects were due to the complexity of the task. Yet, noticing of the neutral unexpected object was high and we still found that more participants noticed the reward-associated object than the cost-associated one: Complexity does not appear to explain our results. If anything, it may have made our task better represent the complexity of the tasks we perform outside of the laboratory.

Our finding is surprising considering that people tend to prioritize threatening information and take longer to disengage from threats (Belopolsky, Devue, & Theeuwes, 2011; Fox, Russo, Bowles, & Dutton, 2007). It suggests that the processes that affect focused attention differ from the ones that affect attention capture. This dissociation between these processes of focused attention and attention capture is consistent with recent work showing no relationship between performance in classic attention capture paradigms and the noticing of unexpected objects in a sustained inattentional blindness paradigm (Wright, Roque, Boot, & Stothart, in revision; see also Most et al, 2005).

Our study is not free of limitations. Consequences in our game came in the form of increases or deductions in an arbitrary point system. Perhaps more consequential objects or events, those that could result in injury or death, would be noticed more often. Our experiments

show little effect of the features we prioritize in a task, but they do not eliminate the possibility that other consequences, including more direct ones from the unexpected object itself, might affect noticing. Future research should explore whether unexpected objects that have consequences for task performance would be more likely to be noticed. If, as in our experiments, objects with more direct costs are no more likely to be noticed than those with no costs, the implications for risks in daily life would be more substantial. It would help explain why life-threatening events—like a bear in your path—can go unnoticed.

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