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The Influence of Attention Set, Working Memory Capacity, and Expectations on Inattentional Blindness

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Abstract

The probability of inattentional blindness, the failure to notice an unexpected object when attention is engaged on some primary task, is influenced by contextual factors like task demands, features of the unexpected object, and the observer's attention set. However, predicting who will notice an unexpected object and who will remain inattentionally blind has proven difficult, and the evidence that individual differences in cognition affect noticing remains ambiguous. We hypothesized that greater working memory capacity might modulate the effect of attention sets on noticing because working memory is associated with the ability to focus attention selectively. People with greater working memory capacity might be better able to attend selectively to target items, thereby increasing the chances of noticing unexpected objects that were similar to the attended items while decreasing the odds of noticing unexpected objects that differed from the attended items. Our study ($N = 120$ participants) replicated evidence that task-induced attention sets modulate noticing but found no link between noticing and working memory capacity. Our results are largely consistent with the idea that individual differences in working memory capacity do not predict noticing of unexpected objects in an inattentional blindness task.

Keywords

inattentional blindness, attention set, working memory, expectation

People sometimes fail to notice unexpected objects when their attention is engaged in another task, a finding known as inattentional blindness (Mack & Rock, 1998). These failures of

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awareness occur in a wide variety of laboratory and real-world situations, and for many types of unexpected stimuli (Chabris, Weinberger, Fontaine, & Simons, 2011; Drew, Vo, & Wolfe, 2013; Furley, Memmert, & Heller, 2010; Haines, 1991; Hyman, Boss, Wise, McKenzie, & Caggiano, 2010; Koivisto & Revonsuo, 2007; Most, Simons, Scholl, & Chabris, 2000; Newby & Rock, 1998; Simons & Chabris, 1999).

Inattention blindness rates are strongly influenced by the nature of the object and task, including the characteristics of the unexpected object (e.g., size: Mack & Rock, 1998; animacy: Calvillo & Jackson, 2014; self-relevance: Mack, Pappas, Silverman, & Gay, 2002), the unexpected object's distance from the attentional focus (Most, et al., 2000; Newby & Rock, 1998), and the perceptual and cognitive demands of the task at hand (Cartwright-Finch & Lavie, 2006; de Fockert & Bremner, 2011; Fougnie & Marois, 2007). Noticing rates are also strongly determined by the observer's goals or attention set: Unexpected objects that are perceptually or semantically similar to the attended items are noticed more frequently than those that differ from the attended items (Koivisto & Revonsuo, 2007; Most, Scholl, Clifford, & Simons, 2005; Most et al., 2001).

In contrast to such task-based influences on detection, the evidence for individual differences in susceptibility to inattentional blindness is mixed and murky. For example, some studies link inattentional blindness to working memory capacity (Hannon & Richards, 2010; Richards, Hannon, & Derakshan, 2010), but two other large-scale studies found no link (Bredemeier & Simons, 2012). Still others find an association that depends on the difficulty of the primary task (Calvillo & Jackson, 2014) or the particular inattentional blindness task used (Kreitz, Furley, Simons, & Memmert, 2015), or they find an association only for a subset of participants (Seegmiller, Watson, & Strayer, 2011).

We sought to clarify the relationship between working memory capacity and inattentional blindness by exploring whether working memory might modulate the effect of attention sets on noticing. People with greater working memory capacity can use their cognitive resources more flexibly, better adjusting their attention to the task requirements (Bleckley, Durso, Crutchfield, Engle, & Khanna, 2003; Kane & Engle, 2003). Working memory capacity is associated with enhanced attentional control (Kane, Bleckley, Conway, & Engle, 2001; Kreitz, Furley, Memmert, & Simons, 2014); people with high working memory capacity can control their attention more effectively in favor of task- and goal-relevant information. For example, in a dichotic listening task, people with greater working memory can better detect items in either stream when asked to spread their attention across both (Colflesh & Conway, 2007). However, when asked to focus attention on just one stream, they are less likely to detect unexpected objects in the ignored stream (Conway, Cowan, & Bunting, 2001). That is, when given a focused attention task, they can ignore distracting information more effectively than can people with lower capacity (see also Kane et al., 2001; Kane & Engle, 2003).

This ability to focus attention is akin to an attention set; people with higher working memory capacity can better focus on those elements of a scene that interest them, while more effectively filtering those aspects that do not. Given the link between attention sets and noticing in inattentional blindness tasks (Koivisto & Revonsuo, 2007; Most et al., 2001, 2005), we hypothesized that working memory capacity would modulate the effect of attention sets on noticing. When an inattentional blindness task requires participants to focus selectively on target items while ignoring distractor items, observers form an attention set that distinguishes targets from distractors. Such an attention set leads to higher noticing rates for unexpected objects that share features with the attended stimuli. For example, when attending to black shapes and ignoring white shapes, people are more likely to notice unexpected black items than unexpected white items (Most et al., 2001). But, attention sets are not all-or-none, and the match between an object and an attention set can vary more continuously. For example, when attending to black shapes and ignoring white shapes, people are more likely to notice unexpected black items than unexpected dark grey items, and they are more likely to notice dark grey items than light grey items (Most et al., 2001).

Other inattentional blindness studies that explored individual differences in working memory capacity have used unexpected objects that happened to match or mismatch the observer's attention set, although those studies were not designed to explore the role of attention set directly. For example, Bredemeier and Simons (2012) asked participants to track white items and presented an unexpected dark grey object (mismatch) whereas Seegmiller et al. (2011) asked participants to track players wearing black shirt and presented a matching unexpected object, a person in a black gorilla suit (see Simons & Chabris, 1999). Somewhat consistent with our predictions, Bredemeier and Simons (2012) found a slight, non-significant trend toward a negative relationship between noticing and working memory capacity whereas Seegmiller et al. (2011) observed a positive relationship between working memory capacity and noticing among the subset of participants who completed the primary task accurately.

We hypothesized that the effect of task-induced attention sets would be stronger for people with higher working memory capacity. Compared with participants with a lower working memory capacity, they should be more likely to notice unexpected objects that match the target items and less likely to notice those that differ from the target items.

To explore this possibility, we used a dynamic inattentional blindness task in which participants tracked either white or black targets and the unexpected object could be either dark grey or light grey. This task induces an attention set for the target color, yielding greater noticing for similar unexpected objects (Most et al., 2001). We did not use unexpected objects that perfectly matched the attended or ignored items because people almost always notice unexpected objects that perfectly match their attention set and rarely notice those that match the ignored items (Most et al., 2001). To avoid such ceiling and floor effects on noticing, we used intermediate levels of grey, relying on the finding that effects of attention sets operate more continuously rather than in an all-or-none match or mismatch way (Most et al., 2001).

In contrast to previous studies exploring the link between noticing and working memory (Bredemeier & Simons, 2012; Seegmiller et al., 2011), we included both an attention set match and an attention set mismatch, allowing a direct test of our hypothesized role for working memory. We also equated the subjective difficulty of the primary task across participants (adaptive thresholding) on the critical trial in order to isolate the effect of individual differences in working memory capacity from the ability to perform the primary task. Finally, we counterbalanced the luminance of the attended items and the unexpected object across participants to control for possible differences in noticing due to the specific stimulus parameters.

Method

The study design, testing procedures, and analysis plan were preregistered on the Open Science Framework. The preregistration and all of the code and data are available at https://osf.io/gcrvz/ and https://osf.io/p6rnt/.

Participants

A total of 120 undergraduate students completed the tasks in a single session (approximately one hour) in exchange for 10 Euro. Data from five of these participants were excluded from the analyses because they indicated in the follow-up questionnaire either that they had anticipated the unexpected object or that they had known that the study was testing inattentional blindness. The final sample in the analysis included the remaining 115 participants ($M = 21.8$ years; $SD = 2.6$ years; 39 female). The number of participants in each condition along with the number of noticers is shown in Table 1.

Materials and Procedure

Participants were tested alone or in pairs. When tested in pairs, they were separated by dividers and were instructed to work quietly. Detailed instructions appeared on screen prior to each task. Participants first completed an inattentional blindness task and then completed three working memory tasks in a randomized order (when two participants took part simultaneously, they received the same random order of working memory tasks). The tasks and materials are described later.

Inattentional blindness task. The inattentional blindness task was adapted from Most et al. (2001). On each trial, four white and four black T and L shapes ($1.15^\circ \times 1.15^\circ$) moved within a grey window (RGB: 128,128,128; $20.3^\circ \times 15.2^\circ$). Participants were instructed to fixate a small blue square that was centered in the window and to count the total number of times that the black letters (half of the participants) or the white letters (half of the participants) bounced off the edges of the display. All eight letters moved on random linear paths and changed direction whenever they touched the edge of the window (for a detailed description of possible rebound angles, see Simons & Jensen, 2009). Whenever two stimuli occluded each other, the monitored stimuli covered the ignored ones. Each trial lasted 8,900 ms with a 600-ms frozen start screen, 8,000 ms of motion, and a 300-ms frozen end screen. After each trial, participants were prompted to type the total number of bounces that they had counted. The counts were treated as correct if they were within 20% of the correct answer (rounded up; see Simons & Jensen, 2009).

After six practice trials, participants completed a set of trials in which the speed of the letters was adaptively adjusted: An incorrect count on one trial led to slower motion on the next trial, whereas accurate counts led to faster motion. This adaptive thresholding procedure (3-1 method; Levitt, 1971) determined the speed of the letters at which the participant could respond accurately 79% of the time.

Once the threshold was determined, the critical trial occurred next, without any forewarning. On the critical trial, the letters moved at the threshold speed, and after 2 s, a grey cross ($0.9^\circ \times 0.9^\circ$) entered vertically centered on the right side of the display, traveled horizontally across the display, and exited on the left 4.4 s later. By using each participant's threshold speed on the critical trial, we equated the subjective difficulty of the primary task

Table 1. Number of Participants, Noticing Rates, and Working Memory Scores in the Two Conditions.

	N_{before}	N_{after}	Number noticing	% noticing	Aospan	2-back-identity	2-back-spatial
Match	60	56	53	94.6	34.8 (15.7)	16.8 (5.3)	16.6 (5.7)
Mismatch	60	59	27	45.8	40.7 (15.3)	17.7 (4.6)	17.0 (5.1)

Note. N_{before} = number of participants before exclusion, N_{after} = number of participants after exclusion, standard deviation in brackets, scores for the three working memory measures are those described in the method section.

between participants. By doing so, we could isolate the relationship among working memory, attention sets, and noticing from the ability to perform the primary task.

For half of the participants, the unexpected cross was light grey (RGB: 191,191,191), and for half it was dark grey (RGB: 64,64,64). Consequently, for half of the participants, the color of the unexpected object was more similar to the attended items (the match condition: light grey cross when tracking white letters or dark grey cross when tracking black letters), and for half of the participants, it was more similar to the ignored items (the mismatch condition: light grey cross when tracking black letters or dark grey cross when tracking white letters).

On the critical trial, after reporting their total count, participants were asked if they had seen anything other than the letters during that trial. Independent of their answer, they then were asked which direction the additional object had moved (left to right, right to left), what color it had been (grey, blue, red, green, yellow), and what shape it had been (rectangle, square, triangle, diamond, cross, 45° rotated cross). They were instructed to guess if they had not noticed anything. After completing three more trials without an additional object, the same critical object appeared again (divided-attention trial). Finally, after answering an identical set of questions, participants completed one more trial in which they were instructed not to count the bounces, with the same critical object appearing again (full-attention trial).

2-back-identity. A sequence of 100 letters (C, F, K, M, P, S, W, X; each was 1.7° of visual angle) appeared centrally on the display. Each letter was presented for 500 ms and was followed by a 2,000 ms blank screen. Participants pressed a button whenever a letter matched the one presented two items earlier in the sequence (adapted from Owen, McMillan, Laird, & Bullmore, 2005). Twenty-five of the letters in the sequence were matches. Participants were instructed to respond as quickly and accurately as possible. Prior to the experimental sequence, participants completed a 20-item practice sequence (without feedback). The measure of working memory in this task was Pr (i.e., hits minus false alarms; Snodgrass & Corwin, 1988).

2-back-spatial. The procedure was the same as for the 2-back-identity task except that in place of the letters, circles (2° diameter) appeared sequentially at eight different spatial locations (arranged equally spaced on an imaginary circle with a diameter of 15°), and participants responded whenever the current circle location matched the location two items earlier (adapted from Boot, Kramer, Simons, Fabiani & Gratton, 2008). Again, the measure was Pr.

Automated operation span (Aospan). Participants memorized lists of letters while simultaneously solving simple mathematical problems (Unsworth, Heitz, Schrock, & Engle, 2005). The Aospan task included 15 trials (3 trials each with 3, 4, 5, 6, and 7 letters to memorize). As a measure of working memory, we used the total number of letters recalled across all error-free trials (the Ospan score; Unsworth et al., 2005).

Materials and setup. The inattentional blindness task, the 2-back-identity task, and the 2-back-spatial task were programmed and run in Presentation (Neurobehavioral Systems, Berkeley, CA). The Aospan was programmed and run in E-Prime 2.0 (Psychology Software Tools, Pittsburgh, PA). Participants responded via a standard keyboard or, in case of the Aospan, a standard mouse. For the inattentional blindness task, a chin rest (NovaVision, Magdeburg, Germany) was used which ensured an exact viewing distance of 50 cm from the 24-inch display (resolution: 1,920 × 1,080 pixels, controlled by an Esprimo 710 3.3 GHz Core i3-3220 computer). For the three working memory tasks, participants sat approximately 50 cm from the display.

Results

Due to computer error, data were missing from one participant for the 2-back-identity task, one participant for the 2-back-spatial task, and two participants for the Aospan task. The correlational analyses reported below included all participants for whom we had data for both tasks. Following recent best practice recommendations (Cumming, 2012, 2014), we report effect-size estimates and their precision (95% confidence intervals) rather than conducting null-hypothesis significance tests.

Participants were coded as inattentionally blind if they did not report noticing the unexpected object or if they claimed to have seen something but could not define at least two of the following three features of the unexpected object: its movement direction, its color, or its shape. All participants noticed and correctly identified the unexpected object in the full-attention trial. Thus, a failure to report the unexpected cross on the critical trial can be attributed to the absence of attention rather than to the limits of vision (Mack & Rock, 1998).

Figure 1 depicts the inattentional blindness rates for the different conditions and trials. On the critical trial, 94.6% of the participants in the match conditions and 45.8% of the

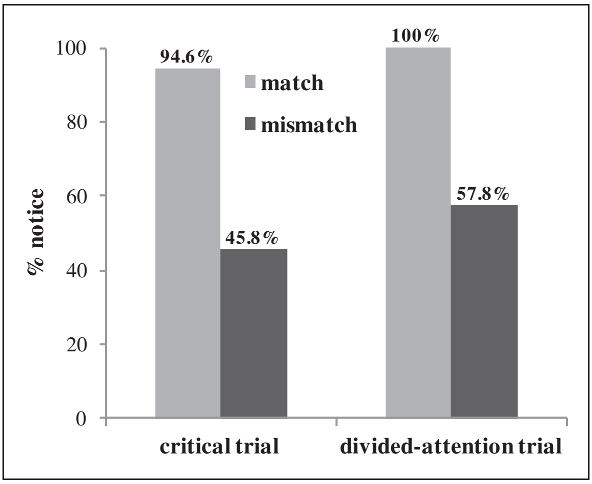

Figure 1. Percentage of participants in the match condition and in the mismatch condition who noticed the unexpected object. Results are illustrated separately for the critical trial and the divided-attention trial.

Table 2. Correlations (Pearson's *r*) Among the Working Memory Measures.

	2-back-identity	2-back-spatial	Aospan
2-back-identity	–	.55 [.41, .67]	.40 [.23, .55]
2-back-spatial	113	–	.32 [.14, .48]
Aospan	112	112	–

Note. The lower and upper bounds of the 95% confidence interval are shown in brackets, and the number of cases contributing to each correlation appear below the diagonal.

participants in the mismatch conditions noticed the unexpected object. Thus, participants were approximately twice as likely to notice the unexpected object if its color matched their attention set than when it mismatched their attention set, risk ratio (match/mismatch) = 2.07 [1.91, 2.24]. The same pattern was evident in the divided-attention trial: 100% of the

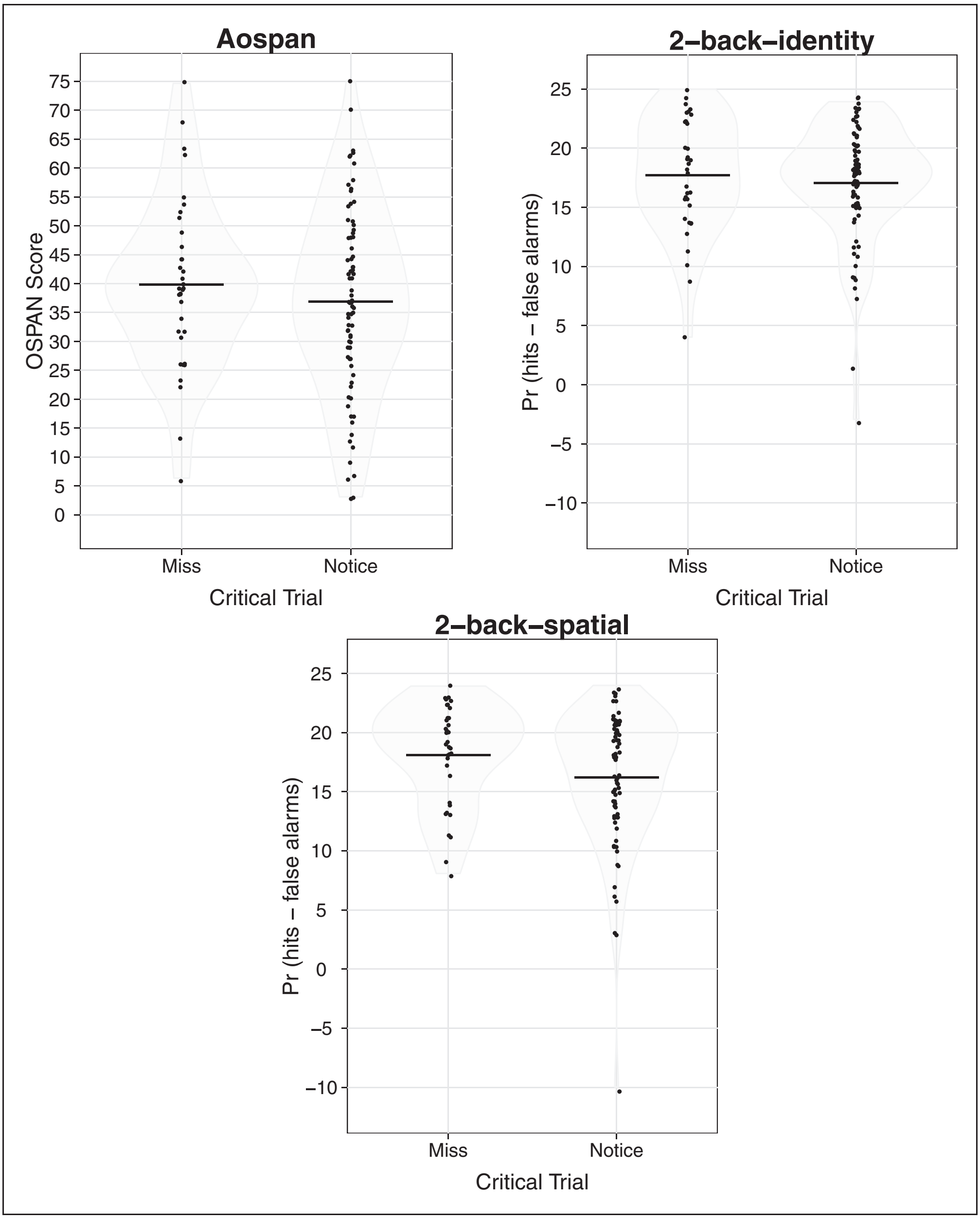

Figure 2. The distribution of scores on each memory measure for people who missed or noticed the unexpected object on the critical trial. Within each panel, each dot represents one participant's score, the horizontal lines show the means across participants, and the violin plots show the density of scores.

participants noticed the unexpected object in the match condition, whereas only 57.6% noticed it in the mismatch condition, risk ratio (match/mismatch) = 1.73 [1.39, 2.16].[1]

Noticing rates were only 11.8% higher in the divided-attention trial than the critical trial for the mismatch condition, risk ratio (divided attention/critical) = 1.26 [0.88, 1.79]. Twenty-one of the 32 participants (65.6%) who were inattentionally blind in the mismatch condition also missed the unexpected object when it appeared in the divided-attention trial. Even 4 (14.8%) of the 27 participants who noticed the unexpected object in the critical trial of the mismatch condition missed it in the divided-attention trial. Apparently, when the critical item differs from the attended items, inattentional blindness can occur at a high rate even when people know it might appear.

To analyze the relationship between working memory performance and noticing, we created a composite working memory measure by z-scoring each measure and averaging these z-scores for each participant. This approach seemed reasonable given that the three working memory measures were intercorrelated in our sample with medium to high strength (Cohen, 1988; see Table 2). For the mismatch condition, we predicted a negative correlation between noticing and working memory, but the two were only minimally related, $r = -.04$ [−.29, .22]. In the match condition, noticing rates were near ceiling (94.6% of participants noticed), and only three participants missed the unexpected object. Consequently, the unexpectedly negative correlation between noticing and working memory, $r = -.17$ [−.41, .10] is not particularly meaningful.

Although we used a composite memory measure for these planned analyses, a recent meta-analysis (Redick & Lindsey, 2013) suggests that complex span tasks like the Aospan and n-back measures are not equivalent measures of working memory; they do not share sufficient variance to be used interchangeably. Although we found sizable correlations among our working memory measures, in light of this meta-analytic result, we additionally explored the relationship between each working memory measures and inattentional blindness. Noticing the unexpected object in the mismatch condition was not correlated with performance on the 2-back-identity task, $r = .02$ [−.24, .28], or with performance on the Aospan, $r = .12$ [−.14, .37], and it was weakly negatively correlated with performance on the 2-back-spatial task, $r = -.23$ [−.46, .03]. Again, for the match condition, noticing rates were sufficiently high to render correlations between our working memory measures and noticing effectively meaningless, 2-back-identity: $r = -.12$ [−.37, .15]; 2-back-spatial: $r = -.09$ [−.35, .18]; Aospan: $r = -.21$ [−.45, .06]. Figure 2 shows that for all three working memory measures, the mean and distribution of scores did not vary between participants who noticed the unexpected object in the critical trial and those who did not.[2]

Discussion

We examined whether the link between inattentional blindness and the observer's attention set is moderated by individual differences in working memory capacity. We hypothesized that participants with greater working memory capacity would show an amplified effect of task-induced attention set. Instead, we found little evidence for any link between noticing and working memory. Participants with higher working memory capacity were not more likely to detect an unexpected object that matched their attention set (although almost all participants noticed the unexpected object in the match condition, rendering these correlations relatively meaningless). Nor were they more likely to miss an unexpected object that matched the ignored items. Although people with higher working memory capacity use their cognitive resources more flexibly (Bleckley et al., 2003), better adjust their attention to the requirements of the task (Colflesh & Conway, 2007; Conway et al., 2001), and better inhibit distracting stimuli (Kane et al., 2001; Kane & Engle, 2003), these abilities do not translate into a bigger effect of attention set on the detection of unexpected objects.

Our results are consistent with evidence against a robust, reliable relationship between inattentional blindness, and working memory capacity: studies either find no significant relationship (Bredemeier & Simons, 2012), a relatively weak relationship (Hannon & Richards, 2010; Richards et al., 2010), or a relationship that is not robust to task variations or that applies only for a subset of participants (Calvillo & Jackson, 2014; Kreitz et al., 2015; Seegmiller et al., 2011). Consistent with this conclusion, inattentional blindness also appears to be unrelated to other individual differences in cognition, including performance in a Flanker task (Kreitz et al., 2015) or a Stroop task (Richards et al., 2010). Similarly, although anxiety and depression are associated with attentional control deficits, individual differences in anxiety and depression are not associated with inattentional blindness (Bredemeier, Hur, Berenbaum, Heller, & Simons, 2014). Taken together, these findings converge on the idea that the mechanisms underlying the detection of unexpected objects differ fundamentally from those underlying the processing of expected distracters.

Although we found no robust link between inattentional blindness and individual differences in working memory capacity, we did replicate previous evidence for a strong link between the task-induced attention set and the probability of inattentional blindness. Unexpected objects that share features (Most et al., 2001) or semantic content (Koivisto & Revonsuo, 2007) with the attended items are detected more frequently. More than twice as many participants noticed the unexpected object in the match condition than in the mismatch condition even though the physical properties of the unexpected object were identical.

Unlike in many other studies of inattentional blindness (e.g., Downing, Bray, Rogers, & Childs, 2004; Koivisto, Hyönä, & Revonsuo, 2004; Mack & Rock, 1998; White & Aimola Davies, 2008), many of our participants missed the unexpected object when it was presented for a second time (the divided-attention trial). Although some observers in previous studies missed the unexpected object on the divided-attention trial (or on a second critical trial after having noticed the unexpected object on a first critical trial; Bressan & Pizzighello, 2008), noticing rates typically are considerably higher the second time the "unexpected" object appears (Most et al., 2000; O'Shea & Fieo, 2014). Yet, about half of the participants in our mismatch condition missed the unexpected object on the divided-attention trial, even though they knew that an additional object might appear. This substantial inattentional blindness rate contrasts with the near absence of inattentional blindness in the match condition: When the features of the critical object matched the attention set induced by the primary task, 95% of the observers noticed the object even when they were not expecting it. Thus, matching the attention set more than doubled the detection rate of the unexpected object, but the expectation that it might appear again only increased the probability that the critical stimulus would be noticed by a factor of 1.26.

The contributions of both expectations and attention sets to noticing are well established (Downing et al., 2004; Koivisto et al., 2004; Koivisto & Revonsuo, 2007; Most et al., 2001). However, to the best of our knowledge, they have not been discussed in combination. Normally, after participants are first asked about the appearance of an additional object, they devote some resources to the searching for it on subsequent trials, leading to ceiling levels of noticing. We here show that if the features of the critical object mismatch the attention set that is established by the primary task, a critical object goes unnoticed with a high probability even though it is not completely unexpected any more (see also Aimola Davies, Waterman, White, & Davies, 2013; Most et al., 2001). Thus, we demonstrate that the influence of an attention set can override expectations for the appearance of an additional object.

Inattentional blindness occurs not just in the lab, but also in real-world scenarios (e.g., Chabris et al., 2011; Charlton & Starkey, 2013; Hyman et al., 2010). And, with more naturalistic tasks, attention sets can play an important role as well. For example, changes in the induced attention set can influence the odds of crashes in a driving-related task; vehicles whose color mismatched the induced attention set were missed far more often (Most & Astur, 2007).

If our finding in the divided-attention trial also generalizes beyond a laboratory task, it would mean expectations alone, even a precise expectation for the nature of the critical object or event, might not protect against inattentional blindness. For example, a child running into the street in front of your car is a rare event, but it is not completely unexpected. The event might not fit the driver's attention set, and even though it is not completely unexpected, the driver still might not see the child. Similarly, our divided-attention results might help to explain how radiologists can miss an unanticipated tumor when they are searching for a different problem, even though they know that tumors might appear in a radiograph (e.g., see Drew et al., 2013).

Admittedly, in such real-world scenarios, disentangling different reasons for a failure of awareness is more challenging. People can fail to see a motorcycle, for example, because their attention is focused exclusively on cars (inattentional blindness due to a mismatched attention set). Or, they could miss a motorcycle even if it is expected and part of the attention set just because it is a rare event. Without a direct manipulation of the attention set, it is hard to distinguish failures due to mismatched attention sets and those due to the tendency to miss rare items even when we are looking for them.

The divided-attention results also are consistent with recent evidence showing that holding the wrong expectation about what might appear can lead to repeated failures to notice, even when observers know that something else might appear (Ward & Scholl, 2015). The percentage of participants who were repeatedly inattentional blind was even higher in the present study (65.6% vs. 29%). Potentially, the same mechanism underlies both findings: having the wrong attention set. The wrong expectation induced by Ward and Scholl (2015) might have created a new attention set for features matching the first critical object. Because the new critical object lacked those features, it did not match the observer's attention set. In both studies, a narrow attention set might have induced repeated inattentional blindness.

Limitations of the Present Study

On the basis of previous research that used a similar task and stimuli (Most et al., 2001), we had expected that our unexpected objects would be noticed between 44% and 75% for the match condition. That rate of noticing would have permitted more meaningful correlations with working memory. Unfortunately, noticing rates in our match condition were near ceiling levels, rendering those particular correlations meaningless. Future research could use an unexpected object that differs more from the attended items in an attempt to look at correlations for the match condition as well as for the mismatch condition. This would, however, weaken the match between the attention set and the unexpected object even more. Another approach might be to establish a semantic rather than a perceptual attention set (see Koivisto & Revonsuo, 2007). Doing so would also allow for a comparison of the relative effectiveness of perceptual and semantic attention sets and on the relationship between noticing and individual differences in working memory. As higher working memory capacity involves more efficient attentional selection and filtering in a variety of tasks and situations (Bleckley, Foster, & Engle, 2015; Kane et al., 2001; Kane & Engel, 2000, 2003), we would expect findings to be similar for semantic and perceptual attention sets.

In our design, we equated primary-task performance across participants on the critical trial, and doing so might have muted the correlation between working memory and noticing. However, several other studies found no overall association between noticing and primary-task performance in a tracking task (Bredemeier & Simons, 2012; Most et al., 2000, 2001; Simons & Jensen, 2009). Assuming that lack of a relationship is robust, equating primary-task performance should not have masked a correlation between noticing and working memory in our design. Our goal was to explore the relationship among attention sets, working memory, and noticing, independent of primary task performance. Equating primary-task performance was perhaps the best way to do so.

Observing an individual-differences correlation depends on the reliability of the measures involved. Assessing the reliability of an inattentional blindness task is problematic, though, due to the single-trial nature of the phenomenon; an unexpected object is only unexpected once. Moreover, the dichotomous measurement (notice or not) limits the power to detect a correlation. This limitation applies to all individual-difference studies on inattentional blindness (see Kreitz et al., 2015). However, inattentional blindness varies systematically as a function of transient factors such as mood (Becker & Leinenger, 2011), cognitive load (Fougnie & Marois, 2007), or physical arousal (Hüttermann & Memmert, 2012), and it varies predictably with task demands (Mack & Rock, 1998; Most et al., 2001; Simons & Chabris, 1999) and across groups of people (Graham & Burke, 2011; Memmert, 2006; Swettenham et al., 2014). This systematic variability suggests that the failure to find correlations with more stable individual differences is not entirely due to a lack of reliability of inattentional blindness measures.

Still, the ability to detect individual differences may require larger samples due to the dichotomous nature of the measure and the potential limits to reliability. Our sample size was based on the small-to-medium effects observed in prior studies on the relationship between working memory capacity and inattentional blindness (Hannon & Richards, 2010; Richards et al., 2010). Still, if those effects were overestimated, then our sample might have been somewhat underpowered to detect it.

Conclusion

We show that the observer's attention set and expectations fundamentally influence the probability of inattentional blindness, whereas individual differences in working memory capacity do not. The attention set established by the primary task appears to have a greater influence on noticing than expectations about the possibility of an additional object: Inattentional blindness can occur repeatedly in the same study and for the same participant if the critical object is sufficiently distinct from the participant's attention set.

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Author note

The design and analysis plan for this study were preregistered and all plans and data are available at the Open Science Framework (https://osf.io/gcrvz/ and https://osf.io/p6rnt/).

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Ethical statement

All participants gave their informed consent prior to their inclusion in the study and were debriefed afterwards. The work conforms to Standard 8 of the American Psychological Association's Ethical Principles of Psychologist and Code of Conduct.

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Notes

1. Note that these analyses were preregistered based on anticipated noticing rates between 45% and 75% with stimuli like these. The risk ratio should be interpreted with caution given that noticing rates are near ceiling in the match condition.
2. The raw data on which the reported analyses are based are available at the Open Science Framework (https://osf.io/p6rnt/).

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