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BRIEF REPORT

Animacy, perceptual load, and inattentional blindness

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Abstract Inattentional blindness is the failure to notice unexpected objects in a visual scene while engaging in an attention-demanding task. We examined the effects of animacy and perceptual load on inattentional blindness. Participants searched for a category exemplar under low or high perceptual load. On the last trial, the participants were exposed to an unexpected object that was either animate or inanimate. Unexpected objects were detected more frequently when they were animate rather than inanimate, and more frequently with low than with high perceptual loads. We also measured working memory capacity and found that it predicted the detection of unexpected objects, but only with high perceptual loads. The results are consistent with the animate-monitoring hypothesis, which suggests that animate objects capture attention because of the importance of the detection of animate objects in ancestral hunter–gatherer environments.

Keywords Animacy · Inattentional blindness · Perceptual load · Working memory · Evolutionary psychology · Visual attention

Inattentional blindness (IB) is the inability to notice objects that appear in one's line of sight. In typical inattentional blindness studies, an unexpected object appears while participants are engaged in an attention-demanding task. IB has been demonstrated for a variety of unexpected objects and primary tasks (for a review, see Most, Scholl, Clifford, & Simons, 2005), and it has important implications for failures to attend to objects in real-world settings such as automobile driving (Strayer, Drews, & Johnston, 2003) and eyewitness memory (Rivardo et al., 2011).

Several factors affect the susceptibility to IB. One factor is task difficulty. During dynamic-monitoring tasks, complex tracking tasks result in a greater incidence of IB than simple tasks do (Simons & Chabris, 1999), even after controlling for individual differences in participants' ability to perform the primary task (Simons & Jensen, 2009). With static tasks, participants are less likely to notice unexpected objects when the primary task includes a higher perceptual load (e.g., Cartwright-Finch & Lavie, 2007). Thus, in dynamic and static IB studies, difficulty with the primary task increases IB.

The effect of primary-task difficulty on IB is explained by load theory (Lavie, 1995). Providing a compromise between early and late selection views, load theory posits that information is processed late until capacity is exceeded, at which point early selection of information processing will occur (Lavie, 2005). When this theory is applied to IB, unexpected stimuli will receive attention only when the demands of the primary task do not exceed the available capacity (Cartwright-Finch & Lavie, 2007). Therefore, more-difficult primary tasks should result in increased susceptibility to IB.

Another factor that may influence susceptibility to IB is participants' working memory capacity (WMC). Because one of the primary functions of working memory is attentional control (e.g., Kane & Engle, 2003), WMC may be crucial in individual differences in IB. Indeed, individuals with greater WMC tend to be less susceptible to IB than are individuals with lower WMC (Richards, Hannon, & Derakshan, 2010).

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However, this relationship may only exist among individuals who perform well on the primary task (Seegmiller, Watson, & Strayer, 2011), and it may depend on the working memory task assessing executive functioning (Hannon & Richards, 2010). Another study, however, showed that the three separate measures of WMC failed to predict the incidence of IB (Bredemeier & Simons, 2012). These inconsistent findings highlight the need for additional research on the relationship between WMC and IB.

Characteristics of the unexpected objects also affect their detection (Mack, 2003). The nearer to the center of a stimulus display, the more likely it is that individuals will detect it (Most, Simons, Scholl, & Chabris, 2000). Physical similarity between the unexpected object and the objects in the stimulus display, as well as participants' attentional goals, increases detection (e.g., Most et al., 2005). Semantic similarity also plays a role. Participants searching for an exemplar of a specific category are more likely to notice an unexpected object from that category than to notice one from another category (Koivisto & Revonsuo, 2007), and this effect is not diminished with high perceptual loads (Koivisto & Revonsuo, 2009). In addition to the task-specific attentional goals of the participants, personal relevance influences the detection of unexpected objects. Personally meaningful stimuli, such as participants' own names, are less susceptible to IB than are other familiar words (Mack & Rock, 1998).

Animacy may be a meaningful feature that facilitates the detection of unexpected objects. Animate objects' self-propelled and self-determined motions may make them especially meaningful and important to detect in the environment. Evidence supports the importance of attention to animate objects. Individuals look longer at animate than at inanimate objects (Yang et al., 2012); animate objects are located more quickly than inanimate objects (Jackson & Calvillo, 2013); and animate motion is detected more quickly than inanimate motion (Pratt, Radulescu, Guo, & Abrams, 2010). Infants appear to differentiate between animate and inanimate objects (Rakison & Poulin-Dubois, 2001), and the processing of animate and inanimate objects activates different brain regions (e.g., Mormann et al., 2011).

Failure to notice animate objects has likely been detrimental over evolutionary time. Other humans may be friends or foes, and nonhuman animals may be predators or prey. New, Cosmides, and Tooby (2007) proposed the *animate-monitoring hypothesis*, which posits that animate stimuli, due to their importance in humans' ancestral hunter–gatherer environments, may be processed differently than inanimate stimuli. Using a change detection task, New et al. found that changes to animate objects are detected more quickly than changes to inanimate objects. Research in other domains also supports this claim. We found that the negative effects of perceptual load can be partially ameliorated when participants search for animate, rather than inanimate, stimuli—especially those that were relevant in the environments in which humans evolved (Jackson & Calvillo, in press).

The goals of the present study were to examine the effects of animacy and perceptual load on IB and to examine the relationship between WMC and IB. A few studies have used animate unexpected objects. Faces (Devue, Laloyaux, Feyers, Theeuwes, & Brédart, 2009) and silhouettes of human bodies (Downing, Bray, Rogers, & Childs, 2004) are detected more frequently than inanimate objects. We propose, on the basis of the animate-monitoring hypothesis (New et al., 2007), that the animacy of these objects is what reduces their susceptibility to IB, due to the importance of attending to animate objects in humans' ancestral environments.

In the present study, participants searched for a color word among many (high perceptual load) or few (low perceptual load) other words. In the third search trial, an unexpected animate or inanimate image appeared in the center of a screen, and we assessed participants' recognition of the unexpected image. We also assessed participants' WMC. We predicted that participants with a low perceptual load would recognize unexpected objects more frequently than participants with a high perceptual load, and that participants would recognize animate objects more frequently than inanimate objects. We also examined the relationship between recognizing unexpected objects and WMC.

Method

Participants and design

A total of 200 undergraduate students from California State University San Marcos participated in exchange for credit toward the completion of a research requirement in an introductory psychology course. The 49 men and 151 women participating in the study ranged in age from 18 to 51 years (M = 21.07, SD = 4.64) years. For the experiment, we employed a 2 (perceptual load: high or low) × 2 (animacy: animate or inanimate) between-subjects factorial design. The dependent variable was the recognition of the unexpected objects.

Materials and procedure

The materials consisted of an IB task, adapted from Koivisto and Revonsuo (2007, 2009), and the automated operation span task (Aospan; Unsworth, Heitz, Schrock, & Engle, 2005). In the IB task, participants were instructed that they would briefly see a set of words, that one of the words would be the name of a color, and that they should search for the color name and write it down after the words disappeared. In each trial, participants saw a white viewing area with a centered fixation cross for 1 s, followed by a set of words for 1 s, followed by a perceptual mask. Figure 1 illustrates this procedure. We manipulated perceptual load by varying the size of the set of words. We presented half of the participants with trials that contained a color word among five additional words (high load), and the other half with trials that contained a color word among two additional words (low load). In the low-load condition, three "X"s appeared in the location of the additional words for the high-load condition. The words and "X"s appeared equidistant from the centered fixation cross.

Participants were randomly assigned to the four conditions, with an equal number participating in each condition ($n = 50$). They gave informed consent, read the instructions, and completed three practice trials followed by three test trials. In the third test trial, an unexpected object appeared, simultaneously with the words, in the center of the screen. After writing down the color word on this last trial, participants answered questions that assessed their perception of the unexpected picture. Specifically, we asked participants, "Did you notice anything new or additional that was not present in the previous trials?" If they noticed anything other than the words, we asked them to describe what it was. We varied the unexpected object that appeared in the last trial. We presented half of the participants with an illustration of an animate object (animal or human) and the other half with an illustration of an inanimate object (tool or transportation). Examples of the critical trials for the four conditions are presented in Fig. 1.

We used a total of 20 illustrations taken from standardized sets (Bates et al., 2003; Snodgrass & Vanderwart, 1980): five exemplars apiece for the two animate and two inanimate categories. The animals were illustrations of a snake, bear, elephant, mouse, and horse; the humans were illustrations of a woman, man, girl, boy, and baby; the tools were illustrations of a hammer, saw, screwdriver, wrench, and scissors; and the transportation illustrations consisted of an airplane, boat, bus, car, and truck. All illustrations were black-and-white line drawings and were edited to be the same size in their longest dimension. The color words in the three practice and three test trials of the primary task were the first six exemplars of Van Overschelde, Rawson, and Dunlosky's (2003) norms for color: blue, red, green, yellow, purple, and orange.

After completing the last test trial in the IB task, participants completed the Aospan task. In the Aospan, participants attempted to remember series of three to seven letters. Each letter was separated by a math operation [e.g., (2 * 3) – 1 = ?]. Participants saw a letter followed by a math operation, which was followed by a possible answer to the math operation (e.g., 5). Participants judged the truth of the possible answer and then saw another letter, followed by another math operation and possible answer. At the end of the series, participants selected the letters that were presented, in the order that they were presented, among a 3 × 4 matrix of letters. The Aospan produces a score with a range of 0 to 75 on

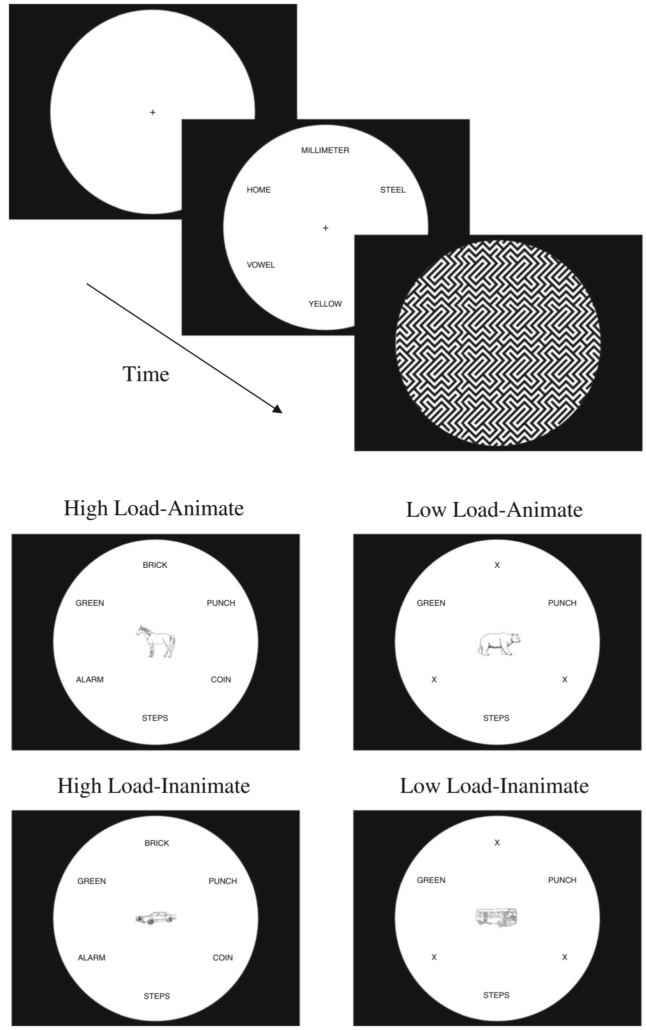

Fig. 1 Examples of the trial sequence (top) and of critical trials for the four conditions (bottom)

the basis of the total number of letters recalled in the correct position across all of the trials. The Aospan was administered using E-Prime 1.0 (Schneider, Eschman, & Zuccolotto, 2002).

Results

Participants reported whether they had noticed anything other than the words on the last trial, and, if so, they described what they had noticed. Following Koivisto and Revonsuo (2007), we coded participants as recognizing the object if they accurately identified the image. In the following analyses of recognition ratings, we report the percentages of participants who recognized the unexpected objects, followed by the 95 % confidence interval (CIs) for those percentages. The CIs were calculated on the basis of the method proposed by E.B. Wilson (1927), and include continuity corrections suggested by Newcombe (1998). Because the CIs were asymmetric, we report the lower and upper limits.

As is illustrated in Fig. 2, recognition rates were dependent on animacy and perceptual load. More participants recognized animate objects (50 % [39.9, 60.1]) than inanimate objects (29 % [20.6, 39.1]), $\chi^2(1, N = 200) = 9.23$, $p = .002$, $\varphi = .22$, and more participants recognized objects under a low perceptual load (51 % [40.9, 61.1]) than under a high perceptual load (28 % [19.7, 38.0]), $\chi^2(1, N = 200) = 11.07$, $p = .001$, $\varphi = .24$. The recognition rates for the two animate categories, humans and animals, were identical (50 % [35.7, 64.3]).

These findings do not appear to be an artifact of one or two of the animate exemplars being frequently recognized. The six most frequently recognized objects were all animate {baby (70 % [35.4, 91.9]), girl (60 % [27.4, 86.3]), man (60 % [27.4, 86.3]), bear (60 % [27.4, 86.3]), horse (60 % [27.4, 86.3]), and snake (60 % [27.4, 86.3])}, and the three most infrequently recognized objects were all inanimate {screwdriver (10 % [0.5, 45.9]), wrench (10 % [0.5, 45.9]), and hammer (20 % [3.5, 55.8])}. The (binomial) probability of this replication across all of the top six recognized exemplars is roughly $p = .016$.

To examine possible interactions of animacy and perceptual load, we examined the effect of animacy separately for the two perceptual-load conditions. In the low-load condition, participants recognized more animate (64 % [49.1, 76.7]) than inanimate unexpected objects (38 % [25.0, 52.8]), $\chi^2(1, N = 100) = 6.76$, $p = .009$, $\varphi = .26$. The effect of animacy failed to reach significance in the high-load condition; participants did not recognize significantly more animate (36 % [23.3, 50.9]) than inanimate (20 % [10.5, 34.1]) objects, $\chi^2(1, N = 100) = 3.18$, $p = .075$, $\varphi = .18$.

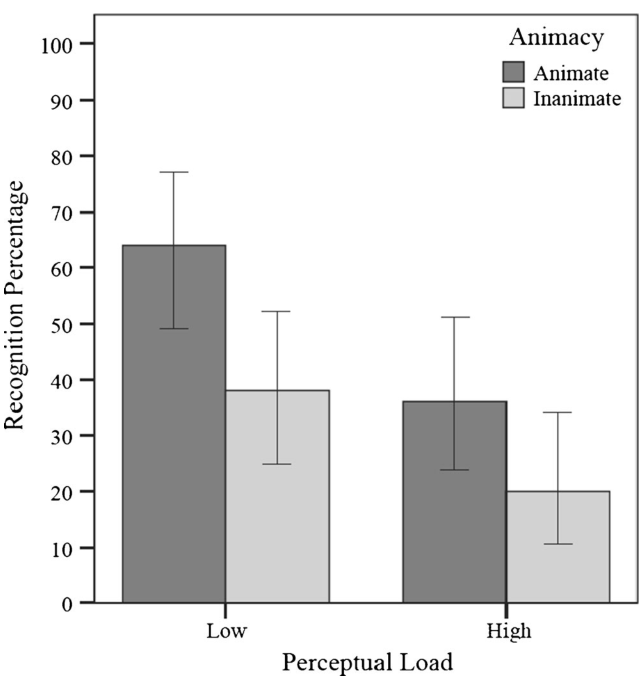

Fig. 2 Recognition of unexpected objects by animacy and perceptual load (error bars show 95 % confidence intervals)

To examine the relationship between working memory capacity and IB, we compared the Aospan scores of participants who recognized the unexpected objects to those who did not. The Aospan scores for 30 participants were considered invalid because their math accuracy was less than 85 % (as recommended by Unsworth et al., 2005). The mean Aospan score for the remaining 170 participants was 53.86 ($SD = 14.11$), which is slightly less than the normed mean from 6,236 individuals (57.26; Redick et al., 2012). Across all conditions, the Aospan scores of participants who recognized the unexpected object ($n = 69$, $M = 56.09$, $SD = 12.70$) were marginally greater than the scores of participants who did not recognize the unexpected object ($n = 101$, $M = 52.34$, $SD = 14.84$), $t(168) = 1.71$, $p = .089$, $d = 0.27$. When separated by perceptual load, the Aospan scores for participants who recognized the unexpected objects under high perceptual load ($n = 20$, $M = 59.80$, $SD = 9.65$) were greater than the scores of those who did not recognize the unexpected objects ($n = 60$, $M = 51.47$, $SD = 15.72$), $t(78) = 2.23$, $p = .029$, $d = 0.64$. This difference was not significant in the low-perceptual-load condition (recognized, $n = 49$, $M = 54.57$, $SD = 13.55$; did not recognize, $n = 41$, $M = 53.61$, $SD = 13.60$), $t(88) = 0.34$, $p = .739$, $d = 0.07$.

Discussion

The results of the present study confirmed our predictions. Participants were less susceptible to IB with animate than with inanimate unexpected objects and with low than with high perceptual loads. The effect of animacy on IB is consistent with the animate-monitoring hypothesis (New et al., 2007): Animate objects appear to capture attention more easily than inanimate objects. The exemplars from the animate categories, animals and humans, were recognized and detected at similar levels. New et al. also found similar preferences for animals and humans over inanimate objects in the time to detect changes in visual scenes.

The finding that participants recognized fewer objects during high than during low perceptual load replicates prior research (e.g., Cartwright-Finch & Lavie, 2007) and supports the load theory of attention (Lavie, 1995). Furthermore, high perceptual load appeared to emolliate the effect of animacy. With low loads, animate objects were detected more frequently than inanimate objects, but this difference was not significant with high perceptual loads. These findings also support load theory. With low perceptual loads, information is selected later in processing, so animacy is processed, whereas with high perceptual loads, information is selected early in processing, and objects' animacy, therefore, may go unprocessed.

It is possible that participants noticed inanimate unexpected items, but due to memory limitations, the memory traces decayed before participants could report what they saw (e.g., Horowitz & Wolfe, 1998). *Inattentional amnesia* occurs when individuals have seen objects but lack the memory of having seen them (Wolfe, 1999). If our findings reflected inattentional amnesia rather than IB, it would suggest that animacy influences memory. Similar retention advantages have been demonstrated for information processed for survival relevance (e.g., Nairne, Thompson, & Pandeirada, 2007), for the location of evolutionarily relevant stimuli in a pelmanism game (Wilson, Darling, & Sykes, 2011), for nonwords paired with animate objects over nonwords paired with inanimate objects (VanArsdall, Nairne, Pandeirada, & Blunt, 2013), and for animate words over inanimate words (Nairne, VanArsdall, Pandeirada, Cogdill, & LeBreton, 2013).

Findings on the relationship between WMC and IB have been inconsistent. Some studies have shown WMC to predict IB, with lower-WMC participants showing greater susceptibility (Richards et al., 2010), whereas others have not shown this relationship (Bredemeier & Simons, 2012). WMC was marginally related to IB in the present study. With high perceptual load, however, participants who recognized the unexpected objects had significantly greater WMC than did those who did not. Consequently, WMC may only predict IB with more difficult primary tasks.

We recommend avenues for future research. The precise features necessary to detect unexpected animate objects warrant further study. Categorization of animate objects shows less of an advantage over inanimate objects when defining features, such as eyes, mouths, and limbs, are not included (Delorme, Richard, & Fabre-Thorpe, 2010). Differences in the detection of different animals could also be examined. Animals that have continually served as an evolutionary threat, such as snakes, may have led to adaptations in anthropoids' visual systems to detect these threats (Isbell, 2006; see also Soares, Esteves, Lundqvist, & Öhman, 2009). In visual search tasks, snakes are detected more quickly than other animate and inanimate objects by both adults and children (e.g., LoBue & DeLoache, 2008). Therefore, snakes may show less susceptibility to IB than do animals that have not continually served as an evolutionary threat. A snake was included as an unexpected object in the present study, but the sample who received each exemplar was too small (n = 10) to make meaningful comparisons within categories. In a recent IB study, spiders captured more eye fixations and greater skin conductance responses than did flowers, but no differences in detection rates emerged (Wiemer, Gerdes, & Pauli, 2013). Snakes may have a special quality (e.g., Öhman & Mineka, 2003), however, that increases detection in an IB task.

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