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Pupillary Response Predicts Multiple Object Tracking Load, Error Rate, and Conscientiousness, but Not Inattentional Blindness

Timothy J. Wright

THE FLORIDA STATE UNIVERSITY
COLLEGE OF ARTS AND SCIENCES

PUPILLARY RESPONSE PREDICTS MULTIPLE OBJECT TRACKING LOAD, ERROR
RATE, AND CONSCIENTIOUSNESS, BUT NOT INATTENTIONAL BLINDNESS

By

TIMOTHY J. WRIGHT

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The members of the supervisory committee were:

Walter Boot
Professor Directing Thesis

Colleen Kelley
Committee Member

Edward Bernat
Committee Member

The Graduate School has verified and approved the above-named committee members, and certifies that the thesis has been approved in accordance with university requirements.

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ABSTRACT

Research on inattentional blindness (IB) has uncovered few individual difference measures that predict failures to detect an unexpected event. Notably, no clear relationship exists between primary task performance and IB. This is perplexing as better task performance is typically associated with increased effort and should result in fewer spare resources to process the unexpected event. We utilized a psychophysiological measure of effort (pupillary response) to explore whether differences in effort devoted to the primary task (multiple object tracking) are related to IB. Pupillary response was sensitive to tracking load and differences in primary task error rates. Furthermore, pupillary response was a better predictor of conscientiousness than primary task errors; errors were uncorrelated with conscientiousness. Despite being sensitive to task load, individual differences in performance and conscientiousness, pupillary response did not distinguish between those who noticed the unexpected event and those who did not. Results provide converging evidence that effort and primary task engagement may be unrelated to IB.

CHAPTER 1

INTRODUCTION

One of the most surprising findings in the study of visual cognition is that when attention is occupied highly salient events can fail to reach awareness (e.g., Mack & Rock, 1998; Neisser & Becklen, 1975; Simons & Chabris, 1999). For example, when observers were asked to view a video and count the number of times a team passed a basketball from one member to another, about half of observers failed to notice a gorilla walk through the scene (Simons & Chabris, 1999). This phenomenon has been termed inattention blindness (IB). Studies examining these failures of awareness have implications for real-world instances of IB that have potentially dangerous consequences. For example, devoting attention to a hands-free cell phone conversation may limit a driver's ability to notice a pedestrian that unexpectedly crosses his or her field of view.

Predicting dangerous failures of awareness would be advantageous. Unfortunately, few reliable indicators distinguish those who are susceptible to IB. Although some studies find that working memory capacity is predictive of IB (Hannon & Richards, 2010; Richards, Hannon, Derakshan, 2010), recently a large study found no such relationship (Bredemeier & Simons, 2012). Most surprisingly, primary task error rate often does not predict IB (Hannon & Richards, 2010; Memmert, 2006; Memmert, Simons, & Grimme, 2009; Most, Simons, Scholl, Jimenez, Clifford, & Chabris, 2001; but see also Bressan & Pizzghello, 2008). This finding is perplexing for a number of reasons. First, according to many resource models of task performance (e.g., Kahneman, 1973; Wickens, 1980; 2002) better performance is typically associated with increased effort recruitment and task engagement, and therefore should result in fewer spare resources to devote to other tasks such as noticing an unexpected event. Furthermore, increased

primary task difficulty, presumably also associated with increased effort and fewer spare resources, is associated with increased IB rates (Cartwright-Finch & Lavie, 2006; Fougne & Marois, 2007; Koivisto & Revonsuo, 2008; Simons & Jensen, 2009). Practice on the primary task, which frees resources to process the unexpected event, also reduces IB (Neisser, 1979; Richards, Hannon, Derakshan, 2010). Why then do individual differences in primary task performance not predict IB? This lack of relationship suggests either that individual differences in primary task effort and IB are unrelated or that error rate is an insensitive measure of effort in the primary task often used to study the phenomenon (i.e., Multiple Object Tracking; MOT).

For a number of reasons, error rate may not be the most appropriate measure of effort recruitment in MOT. First, it does not consider individual differences in baseline ability that different observers bring to the task. To illustrate this point, a hypothetical example is presented. Two observers are participating in a MOT task. The first observer has exceptional MOT ability and only needs to recruit minimal effort to maintain a reasonable error rate in the task. The second observer is lacking in MOT ability and must recruit a significantly greater amount of effort to maintain an equivalent error rate. While both observers are exhibiting equivalent levels of error rate, they are in fact differing greatly in the amount of effort and resources recruited to complete the primary task, and thus are also differing in the amount of spare resources available to detect the unexpected event.

In addition to not considering individual differences in baseline ability, another reason error rate may not be an appropriate measure of effort in MOT is that it can be influenced by individual differences in rules that participants adopt to deal with the primary task and its sometimes ambiguous situations. For example, many tracking tasks ask viewers to count the number of times relevant items bounce off the edges of a confining window. When an object

bounces off of a corner (hitting two edges), it is unclear whether this should count as one or two bounces. In another ambiguous situation, one or more relevant objects may be very close to or touching an edge, but the trial may end before a visible bounce. Observers may adopt different rules for whether or not these situations should count as bounces. Finally, some participants may guess or round up the tally after realizing they may have inadvertently missed a bounce and others might not. These individual differences in rules for the task and its ambiguous situations may lead to better or worse performance independent of effort, and as a result, may confound error rate as a measure of effort.

The above examples provide the motivation for evaluating error rate against another validated measure of effort recruitment, pupil dilation. In a pioneering study, Hess and Polt (1964) observed increased pupil size as the difficulty of math problems increased. Since this initial finding, the pupil's response to mental effort has proven to be robust through numerous replications (for reviews see Beatty, 1982; Beatty & Lucero-Wagoner, 2000) in the initial domain and in other domains, such as memory (Granholm, Asarnow, Sarkin, & Dykes, 1996, Kahneman & Beatty, 1966), language (Beatty & Wagoner, 1978; Just & Carpenter, 1993), and visual search (Porter, Troscianko, & Gilchrist, 2007). This index of mental effort has even been shown to be useful as an individual difference measure (Ahern & Beatty, 1979; Peavler, 1974; Siegle, Steinhauer, Stenger, Konecky & Carter, 2003). However, to the best of the authors' knowledge, no study has examined pupillary response in MOT. In sum, these studies establish both the utility of pupil measures as sensitive measures of effort recruitment and the potential advantages of employing these measures to distinguish those with few spare attentional resources available to devote to a secondary task, compared to a behavioral measure such as error rate.

The current experiment examined whether pupillary response is a sensitive measure of effort in the primary task and whether effort recruited to complete the primary task could predict IB. Pupil size was obtained while observers completed a MOT task, and tracking load was manipulated (tracking 1 vs. 4 objects). It was hypothesized that:

- 1) Observers would have increased pupil dilation under high load. Additionally, it was expected that the size of this increase would vary by individual (e.g. some individuals would recruit more effort to complete the MOT task as the task became more difficult).
- 2) As a measure of primary task effort, pupil dilation would predict primary task accuracy.
- 3) Simons and Jensen (2009) suggested that individual differences in conscientiousness might determine the amount of effort participants devoted to the primary task. Thus, it was expected that more conscientious participants (measured via the Ten Item Personality Inventory) would recruit more effort and demonstrate a greater pupillary response as a function of increased load, even if conscientiousness was found to be unrelated to error rates.
- 4) Critically, it was expected that if pupillary response was found to be a sensitive measure of effort recruitment, then pupillary response may additionally predict individual differences in IB.

CHAPTER 2

METHODS

Participants

One hundred three Florida State University undergraduates (69 females; mean age = 19.70, $SD = 2.07$) participated for course credit. Twelve participants were excluded from analyses due to incomplete eye data and three were excluded due to primary task error rates greater than two standard deviations above the mean.

Apparatus

An EyeLink 1000 (SR Research Inc.) sampled participants pupil size at 1000 Hz while they viewed a 21-in CRT monitor. Pupil data was downsampled to 100 Hz. A chin rest stabilized head position at 73 cm away from the screen.

Stimuli and Design

Observers fixated a blue fixation point ($.24^\circ \times .24^\circ$) at the center of the screen while they viewed displays consisting of four white and four black letters ($1.57^\circ \times 1.57^\circ$) on a gray background. Letters moved randomly across the screen at a continuous speed of $2.7^\circ/\text{sec}$. Observers' task was to remain fixated centrally and count the number of times white Ts bounced against the edge of a window (a black rectangle) that confined these moving objects ($17.14^\circ \times 13.28^\circ$), while ignoring the bounces of the distractor letters (Figure 1). The number of targets varied per block of trials. On half of the blocks, participants tracked four white Ts (high load) among 2 black Ts and 2 black Ls. On the remaining blocks, participants tracked one white T, among 3 white Ls, 2 black Ts, and 2 black Ls. This condition served as a baseline as it was expected that minimal effort was necessary to complete these blocks. Critically, this minimal effort baseline equated the visual experience of the high load condition and controlled for the

number of objects, amount of motion, and luminance of the display. Accordingly, the number of white (62.52 cd/m^2), black (0.39 cd/m^2), gray (25.41 cd/m^2), and blue (10.21 cd/m^2) pixels was equivalent across low and high load trials.

Figure 1. A screenshot of the type of displays participants viewed. This trial depicts the high load tracking condition (4 targets), and the critical trial in which an unexpected object (gray cross) appears.

The task consisted of fifteen blocks of trials, with each block of trials consisting of four trials (sixty trials total). Blocks alternated between high load and low load. Trials were blocked in order to minimize carryover effects across load conditions. The first two blocks were considered practice and were excluded from analyses. Each trial lasted approximately 8.5 seconds, and following the trial participants were presented with the question, “How many bounces did you count?”. The participant indicated the number of bounces the target letters made with a key press. Following this response, participants were instructed on-screen to initiate the next trial with a key press (i.e., task was self-paced). The critical trial containing the surprise

event was within the final trial of the final high load block. This surprise event was a gray cross ($1.57^\circ \times 1.57^\circ$) that moved laterally from the right to the left of the screen at a speed of $3.4^\circ/\text{sec}$. It was unique in color, shape, speed, and path of motion from the rest of the display.

Awareness of this surprise event was assessed with a survey immediately following the final trial. Observers were considered aware of the surprise event if they specified (via a “yes” or “no” response) they had noticed something unusual during the final trial and provided an accurate description of the surprise event. Also included in this survey was the Ten Item Personality Inventory (TIPI) to provide a brief measure of conscientiousness. The TIPI has been found to provide a quick and valid assessment of personality constructs, as it correlates highly with the Big Five Inventory (Rammstedt & John, 2007).

Effort was operationalized as pupil size increase on the high load trials relative to the low load trials. The final trial containing the unexpected event was excluded from analyses of pupillary response. This trial was not analyzed separately due to the noisy nature of pupil data from a single trial.

CHAPTER 3

RESULTS AND DISCUSSION

Missing Data

Participants were instructed to always fixate the center of the screen and generally complied with instructions. In the reported analyses pupil samples were restricted to those 2.68° (100 pixels) from the central fixation point since video-based eye trackers can be influenced by gaze position (Pomplun & Sunkara, 2003). This restriction resulted in a loss of 6% ($SD = 8\%$) of pupil data. While there was a significantly greater amount of data loss in the high load condition ($M = 6\%$, $SD = 10\%$) compared to the low load condition ($M = 5\%$, $SD = 7\%$), $t(87) = 2.98$, $p < .01$, this difference was extremely small. In addition to fixations outside of the specified boundary, blinks also resulted in instances of missing data. Observers' blinks resulted in a loss of 5% ($SD = 10\%$) of pupil data. High load and low load trials did not significantly differ in data loss due to the number of blinks, $t(87) = 1.17$, $p = .25$.

In sum, 90% ($SD = 13\%$) of the data were retained after excluding samples away from the screen center and blinks. Linear interpolation was used to fill gaps between samples. Missing data at the very beginning or end of a trial could not be estimated using this technique and were instead replaced by the average of the first five valid samples if data were missing from the beginning of the trial, or the last five valid samples recorded if data were missing from the end of the trial. Analyses were run with and without the treatment of missing data, and the pattern of results remained the same. In the reported analyses, pupil data from all trials were included, whether performance on that trial was correct or not.

Pupillary Response and Effort Recruitment

If pupillary response is a sensitive measure of effort in MOT, it is expected to vary with the demands of the task. Averages of pupil size over time during the low and high load trials (time locked to the start of each 8.5 second long trial) were calculated separately and used to determine the proportional increase in pupil size on high load relative to low load trials ((Pupil Size High Load-Pupil Size Low Load)/Pupil Size Low Load) . This created a waveform for each participant representing the increase in pupil size over time as a function of load. In terms of percentage increase, average percentage increase across the entire trial period was significantly different from zero indicating a greater pupil size for high load trials compared to low load trials (Mean difference = 7.3%, $SD = 4.3\%$), $t(87) = 16.04$, $p < .001$. Peak dilation varied substantially by individual: from 4% to 32% for the participants who by this measure demonstrated the smallest and largest increases in effort as a function of increasing task load. Next, we further examine the sensitivity of this measure and potential predictive power with respect to IB.

Pupillary Response vs. Error Rate

To capture effort and relate this to error rates, the area under the curve (AUC) was calculated for each participant based on the waveform representing the proportional increase in pupil size over time for high load vs. low load conditions. Error rates were calculated as the absolute value of the difference between the observer's response and the total number of target bounces divided by the total number of target bounces (Most et al., 2001) across both easy (1 target) and hard (4 target) conditions. While it was expected that the AUC measure would be a more sensitive measure to effort than error rate, it was also expected that error rate and pupillary response would be correlated since error rate would be sensitive to effort as well. Confirming this hypothesis, results showed that AUC was moderately related to error rate, $r(86) = -.42$, $p <$

.001 (Figure 2). Specifically, those individuals who demonstrated minimal pupillary response to task load tended to make the most errors in the task.

Figure 2. Scatterplot illustrating the relationship between error rate and the AUC pupil measure.

Pupillary Response vs. Conscientiousness

In addition, it was expected that more conscientious participants would recruit more effort to complete the primary task. Accordingly, sensitive measures of effort recruitment should be positively related to measures of conscientiousness. Results showed that the AUC was positively related to conscientiousness, $r(85) = .43, p < .001$ (Figure 3); however, error rate was not related to conscientiousness, $r(85) = -.13, p = .24$ (Figure 4).¹ These results suggest that the pupillary response is a more sensitive measure of effort recruitment and conscientiousness than error rate. See Table 1 for a complete correlation matrix for all personality ratings, the AUC pupil measure, and error rate.

Figure 3. Scatterplot illustrating the positive relationship between conscientiousness and the AUC pupil measure.

Figure 4. Scatterplot illustrating the non-significant relationship between conscientiousness and error rate.

Table 1. *Correlation matrix for personality constructs, pupil measure, and error rate.*

		Pupil AUC	Total Error Rate	Prop Increase in Error Rate	Conscientiousness	Agreeableness	Extraversion	Emotional Stability	Openness
Pupil AUC	Pearson Correlation	1	-.415**	-.140	.425**	.094	-.104	-.006	-.011
	Sig. (2-tailed)		.000	.194	.000	.387	.340	.958	.919
	N	88	88	88	87	87	87	87	87
Total Error Rate	Pearson Correlation	-.415**	1	-.035	-.127	-.177	-.056	-.191	-.213*
	Sig. (2-tailed)	.000		.749	.240	.101	.605	.077	.047
	N	88	88	88	87	87	87	87	87
Prop Increase in Error Rate	Pearson Correlation	-.140	-.035	1	-.033	-.080	-.047	-.133	-.127
	Sig. (2-tailed)	.194	.749		.759	.461	.666	.221	.241
	N	88	88	88	87	87	87	87	87
Conscientiousness	Pearson Correlation	.425**	-.127	-.033	1	.155	-.032	.190	.078
	Sig. (2-tailed)	.000	.240	.759		.150	.771	.078	.473
	N	87	87	87	87	87	87	87	87
Agreeableness	Pearson Correlation	.094	-.177	-.080	.155	1	.232*	.191	.175
	Sig. (2-tailed)	.387	.101	.461	.150		.030	.076	.105
	N	87	87	87	87	87	87	87	87
Extraversion	Pearson Correlation	-.104	-.056	-.047	-.032	.232*	1	.154	.113
	Sig. (2-tailed)	.340	.605	.666	.771	.030		.154	.295
	N	87	87	87	87	87	87	87	87
Emotional Stability	Pearson Correlation	-.006	-.191	-.133	.190	.191	.154	1	.127
	Sig. (2-tailed)	.958	.077	.221	.078	.076	.154		.242
	N	87	87	87	87	87	87	87	87
Openness	Pearson Correlation	-.011	-.213*	-.127	.078	.175	.113	.127	1
	Sig. (2-tailed)	.919	.047	.241	.473	.105	.295	.242	
	N	87	87	87	87	87	87	87	87

** Correlation is significant at the 0.01 level (2-tailed).

* Correlation is significant at the 0.05 level (2-tailed).

Personality and IB

We explored personality scores derived from the TIPI and how these personality scores were predictive of IB. The TIPI contains 10 personality trait pairs in which each participant is asked to provide a response on a scale of 1 (strongly disagree) to 7 (strongly agree) regarding the extent to which the specific trait pair applies to his or her personality. Thirty-five observers noticed the unexpected event, while fifty-three observers did not notice the unexpected event. While those who recruited more effort to complete the primary task tended to be more conscientious, those that noticed the unexpected event ($M = 5.46$, $SD = 1.13$) did not significantly differ in conscientiousness from those who did not notice the unexpected event ($M = 5.66$, $SD = 1.04$), $t(85) = -.87$, $p = .38$. This is additional evidence suggesting that effort recruited to complete the primary task is unrelated to IB since highly conscientious individuals would be expected to recruit more effort to perform well. In addition, noticers and non-noticers did not significantly differ in extraversion (noticers: $M = 4.73$, $SD = 1.42$; non-noticers: $M = 4.96$, $SD = 1.37$), $t(85) = -.77$, $p = .45$; emotional stability (noticers: $M = 4.96$, $SD = 1.48$; non-noticers: $M = 5.01$, $SD = 1.20$), $t(85) = -.18$, $p = .86$; and openness (noticers: $M = 5.37$, $SD = 1.12$; non-noticers: $M = 5.38$, $SD = 1.08$), $t(85) = -.02$, $p = .99$. Unexpectedly, there was a trend for noticers ($M = 4.80$, $SD = 1.00$) to report themselves as less agreeable on average than non-noticers ($M = 5.22$, $SD = 1.09$), $t(85) = -1.83$, $p = .07$.² It is important to note that this trend was unexpected (our predictions related solely to conscientiousness), so this finding must be interpreted cautiously.

Pupillary Response and IB

While one potential measure of effort recruitment (conscientiousness) did not distinguish noticers from non-noticers, a more sensitive measure of effort recruitment (pupillary response)

may predict IB if there is indeed a relationship between effort devoted to the primary task and IB. Specifically, those who noticed the unexpected object may have retained sufficient spare attentional resources to detect the event due to less task engagement or allocation of effort to the primary task. Replicating previous findings, overall error rate did not distinguish those that noticed the unexpected event from those that did not notice, $t(86) = -.02, p = .98$. Because the critical trial was included within a block of high load trials, we also explored whether error rate only under conditions of high load would distinguish noticers from non-noticers. It did not, $t(86) = .96, p = .34$. Critically, the more sensitive measure of effort recruitment (the AUC pupil measure) also did not distinguish those that noticed from those that did not, $t(86) = .16, p = .87$ (Figure 5).

Figure 5. Proportional increase in pupillary response on high load trials relative to low load trials for those who noticed the unexpected event and those who did not notice. Standard deviations of AUC are in parentheses.

Finally, we explored the effect of accuracy using a more analogous measure to the pupil measure previously described: the proportional increase in error rate on the hard trials relative to the easy trials was calculated. Surprisingly, this proportional increase in error rate did

distinguish noticers from non-noticers, $t(86) = 2.03, p = .045$, although after correcting for the violation of the assumption of homogeneity of variance this difference did not reach significance, $t(45) = 1.79, p = .08$. Noticers ($M = 1.28, SD = 1.60$) had a larger proportional increase in error rate on the hard trials relative to the easy trials compared to non-noticers ($M = .76, SD = .79$). This might be interpreted as noticers recruiting less effort to meet the demands of the more challenging task, thus having more spare resources to process the unexpected event. However, unlike reported pupillary response, the proportional increase in error rate was not correlated with either overall error rate, pupillary response, or the self-report measure of conscientiousness (Table 1). In sum, results suggest that effort recruited to complete the primary task was not related to IB, as even a more sensitive measure of effort recruitment failed to detect this expected relationship.

CHAPTER 4

CONCLUSIONS

Extending findings in other domains (e.g. Beatty & Wagoner, 1978; Hess & Polt, 1964; Kahneman & Beatty, 1966; Porter, Troscianko, & Gilchrist, 2007), pupillary response was sensitive to task load in a MOT task. Observers exhibited greater pupillary response while tracking four targets compared to one target. Critically, pupillary response to task load was also sensitive to individual differences in conscientiousness and error rate, further validating fluctuations of pupil size as a sensitive measure of effort devoted to the primary task.

Interestingly, pupillary response as a covert measure of effort recruitment was a more sensitive measure of conscientiousness than observers' overt behavior, in which accuracy was not significantly correlated with conscientiousness. However, even as a sensitive measure of effort, pupillary response to task load did not distinguish those who noticed the unexpected event from those who did not, suggesting effort recruited to complete the primary task is unrelated to IB. To the best of the authors' knowledge, this is the first study to demonstrate a significant relationship between pupillary response as a function of mental effort and individual differences in conscientiousness, suggesting that pupillary response to task load might be utilized in conjunction with measures of conscientiousness to cross-validate participants' self-reported personality ratings.

While the results suggest that pupillary response is a more sensitive measure of effort recruited to complete the primary task than error rate, it is worth noting that none of the measures of effort used in the study (i.e., pupillary response, overall error rate, or conscientiousness) were particularly predictive of IB. This converging evidence across measures suggests that effort recruited to complete the primary task does not play a role, or plays only a small role in

producing IB. Although the proportional increase in error rate on the hard trials relative to the easy trials was suggestive as predicting IB, it is unclear whether this is as good of a measure of effort as pupillary response since it was uncorrelated with overall accuracy and conscientiousness.

If effort does not play a large role in producing inattention blindness, what might explain this phenomenon? One potential explanation is that multiple pools of resources exist for the primary task and a secondary task (i.e. detecting an unexpected event). Todd and colleagues (2005) suggest that the primary task involves activation of intraparietal sulcus (IPS), a neural region associated with top-down, goal-driven behavior, whereas the detection of the unexpected stimulus requires activation of the temporo-parietal junction (TPJ), a neural region associated with bottom-up, stimulus driven behavior. This theory at first appears consistent with a separate pool of resources account. Regardless of whether individuals recruit a great deal of resources or minimal resources to complete the primary task, the available pool of resources to detect the unexpected event would remain constant. However, Todd et al. (2005) also found that activation of the IPS suppressed TPJ activity, which is inconsistent with the idea that the depletion of one pool of resources would have no impact on the resources available to detect the unexpected event.

In addition to a separate pool of resource account, individual differences in IB might be explained at least in part by chance coincidence between the location of the unexpected object and the location of attention. Most (2010) distinguishes between *spatial IB* and *central IB*, with the former resulting from an observer's covert attention not aligning with the unexpected object and the latter resulting from insufficient spare resources. The instances of IB in this study may have primarily been spatial IB. This would explain why effort recruitment in the primary task

appears to be unrelated to IB. Those who noticed the unexpected event may by chance have happened to allocate their attention to the right place at the right time. This would seem to be consistent with the finding that unexpected objects that move through an observer's focus of attention are more likely to be noticed (Most, Simons, Scholl, Chabris, 2000).

Finally, it is possible that the current study did not find a relationship between effort recruitment in the primary task and IB because the overall amount of resources recruited alone may not account for individual differences in IB. Instead, the amount of resources recruited relative to an observer's overall pool of resources may need to be considered in order to account for these individual differences. Considering that expertise has been found to distinguish those who notice the unexpected event from those who do not (Memmert, 2006) and experts are likely to bring a larger pool of attentional resources to the primary task, examining how effort recruitment in the primary task predicts IB at various levels of skill may be fruitful. It may be that only the observers who bring a relatively small pool of resources devoted to the primary task are susceptible to IB when this small pool of resources is close to depletion due to high effort recruitment. On the contrary, observers high in skill have large pools of resources, and regardless of whether they recruit a great deal or minimal effort to complete the primary task, their susceptibility to IB is mostly unchanged. This would seem to suggest the possibility that there are "non-IBers" just as there are "non-blinkers" in attention blink tasks (see Martens, Munneke, Smid & Johnson, 2006). These "non-IBers" would tend to always notice the unexpected stimulus. This parallel to the attention blink is even more likely considering that Beanland & Pammer (2012) found that those who are noticers in IB tasks tend to be less susceptible to the attention blink.³ It is important to note that this experiment considers only the observer's overall effort recruited to complete the primary task. Future studies should examine

how an observer's effort recruitment relative to his or her overall pool of resources predict IB by isolating effort from skill in the primary task domain, as other studies examining skill's influence on IB have not adequately dissociated these two factors (Memmert, 2006, Memmert et al., 2009; Simons & Jensen, 2009).

It is important to note that IB is something that varies both within and between individuals. The current study is informative only regarding the extent to which IB varies between individuals. Considering the limitations of pupil data, namely that it is noisy at the individual trial level, the current study cannot examine clearly pupillary response to the critical trial itself. In general, the noisy nature of pupil data presents challenges for its use as an individual difference measure, as there is extreme variability between individuals. However, the large sample utilized in this study hoped to overcome some of these challenges.

In conclusion, predicting instances of IB based on individual differences remains difficult. While the literature suggests that certain primary task demand characteristics and stimulus properties are predictive of incidences of IB (Most et al., 2001; Most, Scholl, Clifford, Simons, 2005), it is still difficult to determine why some individuals fail to notice a surprise event and others notice under identical conditions. Surprisingly, effort recruited to complete the primary task (at least as measured via validated measure of pupillary response) does not appear to be related to these individual differences in IB. This was consistent across multiple measures (i.e., pupillary response to task load and error rate); effort recruited to complete the primary task was unable to distinguish those who noticed the unexpected event from those who did not.

APPENDIX A

IRB APPROVAL

Office of the Vice President For Research
Human Subjects Committee
Tallahassee, Florida 32306-2742
[\(850\) 644-8673](tel:(850)644-8673) · FAX [\(850\) 644-4392](tel:(850)644-4392)

APPROVAL MEMORANDUM

Date: 7/27/2011

To: Timothy Wright

Address: Department of Psychology, 1107 W. Call Street, Tallahassee, FL 32306-4301
Dept.: PSYCHOLOGY DEPARTMENT

From: Thomas L. Jacobson, Chair

Re: Use of Human Subjects in Research
Pupillary Response in Multiple Object Tracking and Predicting Inattentional Blindness

The application that you submitted to this office in regard to the use of human subjects in the research proposal referenced above has been reviewed by the Human Subjects Committee at its meeting on 07/13/2011. Your project was approved by the Committee.

The Human Subjects Committee has not evaluated your proposal for scientific merit, except to weigh the risk to the human participants and the aspects of the proposal related to potential risk and benefit. This approval does not replace any departmental or other approvals, which may be required.

If you submitted a proposed consent form with your application, the approved stamped consent form is attached to this approval notice. Only the stamped version of the consent form may be used in recruiting research subjects.

If the project has not been completed by 7/11/2012 you must request a renewal of approval for continuation of the project. As a courtesy, a renewal notice will be sent to you prior to your expiration date; however, it is your responsibility as the Principal Investigator to timely request renewal of your approval from the Committee.

You are advised that any change in protocol for this project must be reviewed and approved by the Committee prior to implementation of the proposed change in the protocol. A protocol change/amendment form is required to be submitted for approval by the Committee. In addition, federal regulations require that the Principal Investigator promptly report, in writing any unanticipated problems or adverse events involving risks to research subjects or others.

By copy of this memorandum, the Chair of your department and/or your major professor is reminded that he/she is responsible for being informed concerning research projects involving human subjects in the department, and should review protocols as often as needed to insure that the project is being conducted in compliance with our institution and with DHHS regulations.

This institution has an Assurance on file with the Office for Human Research Protection. The Assurance Number is FWA00000168/IRB number IRB00000446.

Cc: Walter Boot, Advisor
HSC No. 2011.6562

APPENDIX B

IRB APPROVAL FOR CHANGE IN PROTOCOL

Office of the Vice President For Research
Human Subjects Committee
Tallahassee, Florida 32306-2742
(850) 644-8673 · FAX (850) 644-4392

APPROVAL MEMORANDUM (for change in research protocol)

Date: 9/27/2011

To: Timothy Wright

Address: Department of Psychology, 1107 W. Call Street, Tallahassee, FL 32306-4301
Dept.: PSYCHOLOGY DEPARTMENT

From: Thomas L. Jacobson, Chair

Re: Use of Human Subjects in Research (Approval for Change in Protocol)
Project entitled: Pupillary Response in Multiple Object Tracking and Predicting Inattentional Blindness

The form that you submitted to this office in regard to the requested change/amendment to your research protocol for the above-referenced project has been reviewed and approved.

If the project has not been completed by 7/11/2012, you must request a renewal of approval for continuation of the project. As a courtesy, a renewal notice will be sent to you prior to your expiration date; however, it is your responsibility as the Principal Investigator to timely request renewal of your approval from the Committee.

By copy of this memorandum, the chairman of your department and/or your major professor is reminded that he/she is responsible for being informed concerning research projects involving human subjects in the department, and should review protocols as often as needed to insure that the project is being conducted in compliance with our institution and with DHHS regulations.

This institution has an Assurance on file with the Office for Human Research Protection. The Assurance Number is FWA00000168/IRB number IRB00000446.

Cc: Walter Boot, Advisor
HSC No. 2011.7128

APPENDIX C

INFORMED CONSENT FORM

FSU Human Subjects Committee Approved on 9/27/2011. Void after 7/11/2012.
HSC# 2011.7128

FSU Behavioral Consent Form

Individual Differences in Multiple Object Tracking

You are invited to be in a research study of how people keep track of multiple objects simultaneously.

You were selected as a possible participant because you contacted our laboratory. We ask that you read this form and ask any questions you may have before agreeing to participate.

This study is being conducted by Walter Boot, Ph.D., from the Department of Psychology at Florida State University.

Background Information:

The purpose of this study is to learn about how people track multiple objects simultaneously when visual environments are often cluttered and complex. Specifically, we are interested in what is related to good tracking performance.

Procedures:

If you agree to be in this study, we would ask you to do the following things: You will view on a computer monitor a window containing many items. These items include letters and shapes of different colors. None of these items are anticipated to induce discomfort; they are items you encounter every day. You will be keep track of specific items (e.g., the white letter T among other black letters). You will be told before each trial which item you should keep track of. You will count the number of times the white target letters bounce off the side of a window. Your accuracy will be recorded. An eye tracking device will record your eye movements as you do the task. A chin-rest will keep your head stationary as your eye movements are tracked. The eye tracking device contains a small camera that will record your eye movements. This camera does not record an image (it does not take your picture), but simply records your eye movements as a series of numbers. The entire experiment will last no longer than forty-five minutes to complete and you will be given the opportunity to take breaks during the experiment.

At the end of the study, we will ask you to fill out a short survey to tell us about yourself and the experiment.

Risks and benefits of being in the Study:

This study has few risks. There are no anticipated risks beyond those of normal everyday computer-based activity. There is a possibility that you may experience some mild frustration if you are unable to perform the task as well as you want. We wish to remind you that you are only

to complete the task as best as you can, and that there are no good or bad scores.

There are no direct benefits to you by participating in this study. However, your participation will serve to enhance our understanding of the mechanisms that underlie visual processing.

Compensation:

You will receive compensation: You will receive one hour of Psychology Subject Pool credit for your participation. If you are uncomfortable performing the task and decide to withdraw from the study, you will not be penalized (i.e., you will receive full payment or credit).

Confidentiality:

The records of this study will be kept private and confidential to the extent permitted by law. In any sort of report we might publish, we will not include any information that will make it possible to identify a subject. Research records will be stored securely and only researchers will have access to the records.

Voluntary Nature of the Study:

Participation in this study is voluntary. Your decision whether or not to participate will not affect your current or future relations with the University. If you decide to participate, you are free to not answer any question or withdraw at any time without affecting those relationships.

Contacts and Questions:

The researcher conducting this study is Dr. Walter Boot. You may ask any question you have now. If you have a question later, you are encouraged to contact Dr. Boot at the Psychology Building (B432 PDB), 217 721 2512, boot@psy.fsu.edu. If you have any questions or concerns regarding this study and would like to talk to someone other than the researcher(s), you are encouraged to contact the FSU IRB at 2010 Levy Street, Research Building B, Suite 276, Tallahassee, FL 32306-2742, or 850-644- 8633, or by email at humansubjects@magnet.fsu.edu. You will be given a copy of this information to keep for your records.

Statement of Consent:

I have read the above information. I have asked questions and have received answers. I consent to participate in the study.

Signature/ Date

Signature of Investigator /Date

ENDNOTES

¹ Degrees of freedom reflect the fact that one participant did not fill out the TIPI.

² Considering that the TIPI was administered following the MOT task and the IB survey, it is possible that participants may have had an idea of whether or not they provided an “agreeable” response. Accordingly, order effects may explain this unexpected finding. We would like to thank an anonymous reviewer for suggesting this possible interpretation.

³ We would like to thank an anonymous reviewer for pointing out this potential parallel between the attention blink and inattention blindness.

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BIOGRAPHICAL SKETCH

Timothy J. Wright

EDUCATION

2015 (in progress)	PH.D., COGNITIVE PSYCHOLOGY Department of Psychology, Florida State University
2013	M.S., COGNITIVE PSYCHOLOGY Department of Psychology, Florida State University
2009	B.A., PSYCHOLOGY Wheeling Jesuit University (summa cum laude)

TEACHING INTERESTS

Visual cognition and attention, sensation and perception, introductory psychology, cognitive psychology, human factors, research methods in psychology, statistics

TEACHING EXPERINCE

Fall 2011 to Spring 2012	T.A. for Research Methods in Psychology Florida State University
Fall 2008 to Spring 2009	T.A. for Statistics for the Behavioral Sciences Wheeling Jesuit University

HONORS AND AWARDS

FSU Outstanding Teaching Assistant Award (nominated), 2012

APAGS/ Psi Chi Junior Scientist Fellowship, 2011

Andrew Scott Wensel Award, 2009 (top researcher among senior psychology majors)

Dennis J. Maceiko Service Award, 2009 (most service oriented senior psychology major)

Wheeling Jesuit University Psychology Outstanding Senior Award, 2009 (top psychology GPA)

WJU Social and Behavioral Sciences Oral Presentation Award, 2009

WJU Social and Behavioral Sciences Poster Presentation Award, 2009

Appalachian College Association Ledford Fellowship, 2008

NASA Space Grant Scholar, 2007 – 2008

PUBLICATIONS

- Blakely, D.P., **Wright, T. J.**, Dehili, V.M., Boot, W.R., & Brockmole, J.R. (2012). Characterizing the time course and nature of attentional disengagement effects. *Vision Research*, 56, 38-48.
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IN PREPARATION, UNDER REVIEW AND SUBMITTED

- Ventura, M., Shute, V., **Wright, T. J.**, Zhao, W., Boot, W. R. (submitted). Environmental spatial ability, STEM interest, and video game use.
- Sall, R., Boot, W. R., & **Wright, T. J.** (in preparation). The effect of red light running camera flashes.
- Wright, T. J.**, Boot, W. R., & Jones, J. (in preparation). Cues imprecise in physical appearance and modality influence attentional disengagement and engagement.

ORAL PRESENTATIONS

- Wright, T. J.**, Boot, W. R., Morgan, C. S. (2012). Who notices the gorilla in our midst? Presented at *The Florida State University Department of Psychology Graduate Research Day*, Tallahassee, FL.
- Blakely, D.P., **Wright, T.**, Boot, W.R., & Brockmole, J.R. (2011). The precision of attention sets: Effects of distractor probability and temporal expectations. Presented at *The Florida State University Department of Psychology Graduate Research Day*, Tallahassee, FL.

Wright, T. & Raudenbush, B. (2009). Interaction effects of visual distractions, auditory distractions and age on pain threshold and tolerance. Presented at the *Wheeling Jesuit University Undergraduate Research Day*, Wheeling, WV.

POSTER PRESENTATIONS

Wright, T. J., Boot, W. R., & Jones, J. (2013). Cues imprecise in modality and physical appearance influence attentional disengagement and saccade direction. Presented at *The 13th Annual Meeting of the Vision Sciences Society*, Naples, FL.

Wright, T. J. & Boot, W. R. (2012). Examining pupillary response as a psychophysiological predictor of inattention blindness. Presented at *The 12th Annual Meeting of the Vision Sciences Society*, Naples, FL.

Wright, T. J. & Boot, W. R. (2012). Utilizing pupillometry to predict inattention blindness. Presented at *The 120th Annual Convention of the American Psychological Association*, Orlando, FL.

Blakely, D.P., **Wright, T.**, Boot, W.R., & Brockmole, J.R. (2011). On the precision of attention sets: Effects of distractor probability and temporal expectations on contingent capture. Presented at *The 11th Annual Meeting of the Vision Sciences Society*, Naples, FL.

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Kolks, J., **Wright, T.**, & Raudenbush, B. (2009). The effects of video game console and snack type on snack consumption during play. Presented at the *Wheeling Jesuit University Undergraduate Research Day*, Wheeling, WV.

Wright, T., McCombs, K., Hunker, R., Bruno, L., Kolks, J., & Raudenbush, B. (2009). Increasing video game performance through the administration of peppermint scent: Application to Nintendo Wii Guitar Hero. Presented at *The 49th Annual Meeting of the Association of Chemoreception Sciences*, Sarasota, FL.

Wright, T. & Raudenbush, B. (2009). The interaction effects of visual and auditory distractions on pain tolerance and threshold in older adults. Presented at *The 49th Annual Meeting of the Society for Psychophysiological Research*, Berlin, Germany.

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