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OBSERVATION

Blinded by Irrelevance: Pure Irrelevance Induced "Blindness"

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To what degree does our representation of the immediate world depend solely on its relevance to what we are currently doing? We examined whether relevance per se can cause "blindness," even when there is no resource limitation. In a novel paradigm, people looked at a colored circle surrounded by a differently colored ring—the task relevance of which was previously manipulated—and were subsequently asked to identify these colors. Whereas knowledge of the task-relevant color was near perfect, up to a quarter of the participants could not name the color of the irrelevant stimulus, even though a control experiment indicated there were sufficient resources to process both stimuli. The results are a first demonstration of blindness when mental resources are clearly available and challenge attentional theories predicting strong selection only when resources are taxed.

Keywords: visual awareness, task relevance, selective attention, inattentional blindness, mental accessibility

> A faint tap per se is not an interesting sound; it may well escape being discriminated from the general rumor of the world. But when it is a signal, as that of a lover on the window-pane, it will hardly go unperceived.
>
> William James, 1890 [p. 418]

This quote makes clear that selective processing has long been a central tenet of psychology. It is widely accepted that our processing resources are inherently limited, and therefore, successful processing of the vast amount of information that reaches our senses requires some form of selection (e.g., Allport, 1987, 1993; Broadbent, 1971; Duncan & Humphreys, 1989; Kahneman, 1973; Posner, 1978). When visual awareness is concerned, selectivity can be surprisingly strong and observers may miss out on very salient and temporally extended visual events if these events were not defined explicitly as task relevant (Neisser & Becklen, 1975). One such striking phenomenon is "inattentional blindness" (Mack & Rock, 1998; Rock, Linnet, & Grant, 1992; Simons & Chabris, 1999).

But what happens when the limited capacity of cognitive processing is not met? Will evidence of such strong selection be found even when the available resources are sufficient for successful processing of both relevant and irrelevant information? The perceptual load theory (e.g., Lavie, 1995; Lavie & Cox, 1997) is one of the prominent current theories of attention, which refers directly to the relation between resources usage and selection efficiency. According to this theory, as long as capacity limitations are not met, perceptual processing proceeds automatically on all stimuli, relevant or not. Once the capacity reaches its limit, irrelevant information can no longer be processed. Thus, according to this theory, demonstration of strong selectivity necessitates the depletion of resources (Cartwright–Finch & Lavie, 2007; Lavie, 2006; Macdonald & Lavie, 2008). Other researchers of attention (e.g., Duncan & Humphreys, 1989) refer only indirectly to a situation in which capacity limitations are not met by suggesting that all available resources are always used. Like the perceptual load theory, this implies that when the processing of task-relevant information does not exhaust all available resources, there should be no evidence of selection.

Adopting this, often implicit, assumption, prior demonstrations of induced blindness always involved situations in which resources were depleted. These involved for example, keeping individual tallies of balls rapidly passed between one or two groups of players (Simons & Chabris, 1999), comparing the length of two rapidly displayed (200 ms), masked and subtly different lines (Rock et al., 1992), searching for a slightly dimmed disk appearing on an outer ring (Pitts, Martinez, & Hillyard, 2012), and continuously monitoring rapidly changing stimulation (Most et al., 2001; Rees, Russell, Frith, & Driver, 1999). That is, these demonstrations were designed to ensure that the main task the participants had to perform (i.e., the explicitly instructed task) was demanding enough, perceptually and/or cognitively, to ensure that available resources were engaged with the processing of task-relevant information. Thus far then, induced blindness is generally accepted to be due to the "draining" of resources by relevant stimuli. Yet this leaves

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open the possibility that irrelevance alone could be sufficient for creating blindness (see Eitam & Higgins, 2010 for related arguments).

We set out to directly examine the prevailing assumption that the depletion of resources is a necessary condition for induced blindness. Specifically, we tested whether evidence of induced blindness can be found even with extremely simple stimuli, presented at the fovea, for relatively long durations, and most importantly, without any substantial mental or perceptual load.

Experiment 1a

The goal of this experiment was to demonstrate pure irrelevance-induced blindness. We employed a very simple task involving a relatively long central presentation of two salient concentric circles with only one deemed relevant. Given this minimal taxing of perceptual and cognitive resources, evidence of induced blindness (i.e., failure to report the color of the irrelevant circle) will indicate strong selection that is based on relevance per se, rather than resource limitation.

Method

Participants. One hundred participants took part in this experiment.

Stimuli and procedure. We used a novel task (Concentric Circles Task; CCT) that involves a single critical trial (see Figure 1). The participants were first asked to focus on the inner or outer (with equal probability) of two to-be-presented concentric circles. After indicating they were ready by pressing a key, they were presented with two differently colored concentric circles at the center of the screen for 500 ms, the combined diameter of which was 3.75°, twice the size of the inner circle alone (1.87°). Hence, neither circle was peripheral in the sense of not falling on the fovea. The ring and circle always differed in color, with one red and the other yellow. The allocation of color was counterbalanced across participants. At 500 ms after the stimulus' offset, participants were presented with a recognition test asking them to choose the color of one of the 2 stimuli (either the relevant or irrelevant stimulus, counterbalanced across participants) out of 3 alternative colors: the correct color, blue, and pink. The locations of the colors in the test were randomized. The participants reported their choice to the experimenter. Stimuli presentation was controlled using PowerPoint.

At the end of each study, participants completed a demographic questionnaire and were asked whether they are color-blind, had any vision problems, or suffered from attention deficiencies. In all the experiments reported here, no consistent differences in recognition performance were found due to these factors or the location (inner vs. outer), color of the relevant circle, or spatial order of options in the recognition test, and hence, these are not further discussed.

Results

To insure the validity of the results, we excluded data from participants who failed in both recognition tests (3 participants, 3%). Supporting the pure relevance hypothesis, relevance had a reliable effect on recognition (see Figure 2). Recognition per-

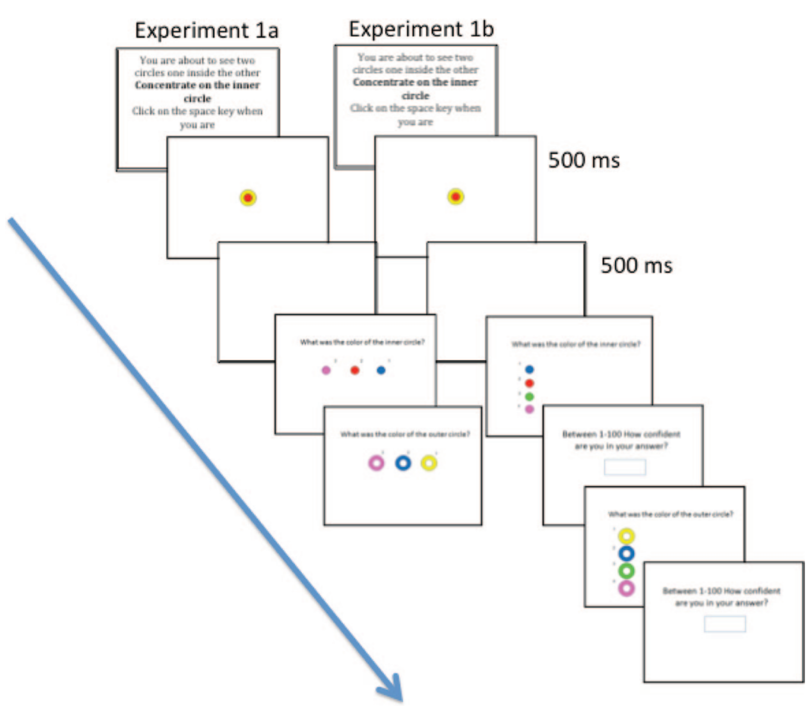

Figure 1. The sequence of stimuli presented to participants in the experiments. Where duration is not marked, transition was self-paced. Experiment 2 was identical to Experiment 1b but for the request to focus on both circles.

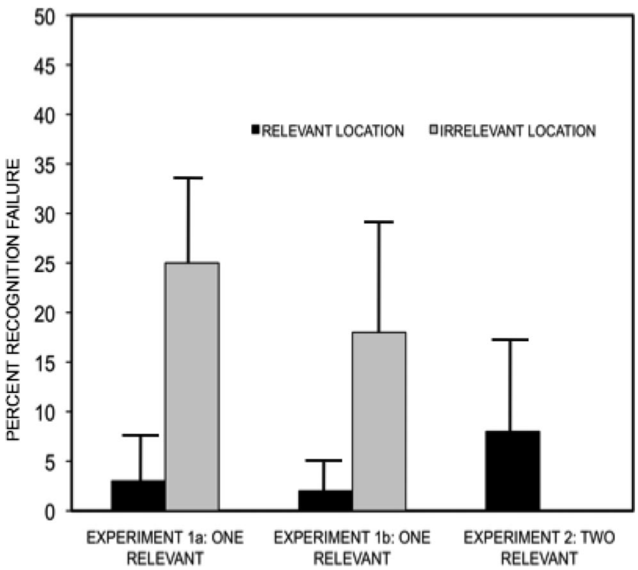

Figure 2. The percent of erroneous recognitions for colors of relevant and irrelevant stimuli in all experiments. The percent of recognition failures shows that people quite easily recognized the color of two circles when both are relevant, but failed in up to 25% of the cases to recognize the color of a single circle when it was irrelevant. Error bars represent 95% confidence intervals.

formance was near perfect for the color of the relevant stimulus (3% erroneous recognitions). This error rate is not reliably different from perfect performance, $z < 1$.[1] Conversely, performance for the color of the irrelevant stimulus was significantly lower with 25% erroneous recognitions, $z = 4.36$, $p < .01$. This pattern held regardless of whether the irrelevant stimulus was the inner or outer circle, or based on the order of recognition tests (relevant first vs. irrelevant first). This effectively rules out the alternatives explanations of eccentricity and forgetting.

Note that a quarter of the attempts at recognizing the irrelevant color were erroneous, even though the irrelevant (and relevant) stimulus was presented for a full 500 ms without masking, and knowledge was probed by a sensitive recognition task that was presented merely 500 ms after the stimulus offset. Contrast this to the classic Rock, Linnet, and Grant (1992) task in which a stimulus was presented for only 200 ms, masked, and probed for (in a recall format) only after another task was completed. To explore the size of the irrelevance effect when using a less sensitive task to evaluate "blindness," we conducted an informal pilot in which we used a free recall memory test. About 50% of the participants failed to correctly recall the irrelevant stimulus.

Because timing using PowerPoint is inaccurate, Experiment 1b was run to validate the pure irrelevance effect with specialized software. Another goal was to explore the effect of pure irrelevance on participants' confidence in their knowledge. Adding a subjective measure enables us to explore whether participants' immediate appreciation of their experience with irrelevant stimuli follows (or dissociates from; Rahnev et al., 2011) their objective recognition performance.

Experiment 1b

Method

Participants. Fifty-six participants took part in this experiment.

Procedure. This experiment was identical to Experiment 1a apart from the following: it was conducted using DirectRT; the recognition test included 4 colors (correct color + blue, green, and pink), and participants responded with a key press. Confidence in the recognition response (on a scale of 1–100) was also measured (see Figure 1).

Results

Recognition rates. As in the previous experiment, participants failing in both recognition tests were excluded (two participants; 4%). Replicating the results of Experiment 1a and in support for pure irrelevance induced blindness, participants' performance was again near perfect for the relevant stimulus with only 2% erroneous responses, which is not statistically different than perfect performance, $z < 1$. In contrast, performance for the irrelevant stimulation was reliably lower with 18% erroneous responses, $z = 2.86$, $p < .01$. As before, this pattern held regardless of the irrelevant stimulus eccentricity or the order of recognition tests.

Confidence level.[2] The data from participants who deviated by 2 standard deviations (*SD*s) from their condition's mean (*M*) confidence level ($n = 6$) were discarded. A paired-means *t* test uncovered that participants were significantly more confident in their report of the color of the relevant ($M = 94.14$, $SD = 15.08$), as compared to the irrelevant circle ($M = 84.67$, $SD = 24.29$), $t_{(48)} = 2.45$, $p < 0.05$, $d = 0.47$.[3] It was important that this pattern held, even when only correct recognitions were included in the analysis, relevant: $M = 96.49$, $SD = 7.46$; irrelevant: $M = 90.90$, $SD = 17.86$; $t_{(40)} = 1.93$, $p < .05$ one-tailed, $d = 0.41$.

In summary, this experiment validates the results of Experiment 1a by demonstrating that pure irrelevance-induced blindness holds for a relatively extended duration of half a second even when millisecond accuracy is employed. Moreover, it demonstrated that confidence rating was lower for the irrelevant colors even when participants recognized them correctly.

Given the simplicity of the main task that merely required participants to look, the central presentation of salient stimuli, and the long exposure duration, we assume that the results of Experiments 1a and 1b are a demonstration of pure (i.e., load-less) irrelevance-induced blindness. To empirically test this assumption, we ran another experiment in which participants were asked to focus on both circles and were then asked to report either the inner

[1] For all analyses involving proportions we used Stata 12 ptest or ptesti command.

[2] We also collected response times. These too show a significant difference in the predicted direction. Because this measure suffers from a potential confound of being surprised by the unexpected (irrelevant color) probe and may lead, in and of itself, to slower response times, we are not presenting them here.

[3] This difference is reliable even if this filter is not used, $t(52) = 2.86$, $p = 0.006$; confidence data from a single participant were lost due to a technical error.

or outer circle. If participants' performance with two relevant circles is similar to performance with a single relevant circle in Experiments 1a and 1b, then we may conclude that participants do have sufficient resources to process both circles. Such a result would render strong support to our pure irrelevance-based blindness.

Experiment 2

Method

Participants. Twenty-six participants took part in this experiment.

Procedure. This experiment was identical to Experiment 1b apart from the following: the participants were asked to focus on both concentric circles. Half of them were first probed on the outer circle, whereas the other half were first probed on the inner circle (note that in this experiment, both were relevant; for a similar strategy in another domain see Eitam, Hassin, & Schul, 2009).

Results

Recognition rates. Only 8% of the responses were erroneous.[4] This error rate is not reliably higher than that observed in Experiments 1a and 1b when recognizing the color of a single relevant circle $M = 3\%$ $z = 1.24$, $p = .2$. It is also not significantly different than perfect performance $z = 1.47$, $p = .14$. Conversely, this error rate is reliably lower than that made by the same participants when recognizing the color of an irrelevant circle $M = 22\%$ $z = 1.65$ $p = .05$ (one-tailed). It is critical there was no significant difference between recognition rates for inner and outer circles ($z = 0.1$, $p = .92$).

Confidence level. Data from participants' whose confidence rating was 2 *SD*s above or below their condition's mean were removed ($n = 3$). Echoing the pattern of recognition performance, participants' confidence in their recognition response ($M = 92.56$, $SD = 12.83$) was not reliably different than that of participants in the single relevant circle condition of Experiment 1b, $M = 94.14$ $SD = 15.08$, $t(71) < 1$, $p = .66$. It should be noted that this level of confidence is also not reliably higher than that displayed by participants for the irrelevant circle in Experiment 1b, $M = 84.67$ $SD = 24.29$, $t(71) = 1.51$, $p = .13$.[5]

In summary, recognition performance in Experiment 2 supports our assumption that, when relevant, participants' can process both circles. The pattern of reported confidence does not currently enable us to reach a clear conclusion.

General Discussion

In support of pure irrelevance-induced "blindness" the results of three experiments clearly show that although people easily recognize the color of one or two relevant stimuli, recognizing the color of an irrelevant stimulus is far more limited. Over all experiments, failure to recognize the color of the extremely simple irrelevant stimulus was almost seven times more probable (21.5% vs. 3.4%). The experiments also revealed that people were less confident of their knowledge regarding the irrelevant stimulus—above and beyond of its validity. Less clear is whether participants' confidence judgments vary when faced with two (vs. one) relevant circles. Future work will have to determine whether this is indeed the case and what are the implications, if any.

In light of the outcome of the three experiments reported here and previous reports of induced blindness, we suggest that there might be two types of induced blindness. Both depend on relevance, but only one depends on relevance alone. The first type reflected in previous demonstrations of induced blindness, such as inattentional blindness and change blindness, occurs when resources are unavailable for the processing of the task-irrelevant stimulus due to their allocation to task-relevant stimuli. We speculate that this type of blindness is phenomenal blindness that entails the lack of visual awareness—such as in the case of not being aware of or not seeing the "gorilla" while it appears (Simons & Chabris, 1999).

The second type of induced blindness, which we have demonstrated here, occurs regardless of available resources. Rather, it is based on irrelevance alone. This type of blindness seems to be what Simons (2000) had in mind when he wrote of inattentional agnosia as not knowing about (and hence not being able to tell) the irrelevant stimuli that were consciously experienced.

Thus, we propose that in our study, the participants who failed to report the irrelevant color were aware of it when it was displayed, but due to irrelevance, its abstract representation (of "red", e.g.) was insufficiently activated (Eitam & Higgins, 2010; Eitam, Miele, & Higgins, in press), or possibly suppressed, and the participants could not report it.[6] If these two types of "blindness" indeed exist then this would support dissociation between awareness and knowledge activation, or access of representation in long-term memory (for frameworks supporting such a dissociation see Eitam & Higgins, 2010; Eitam, Miele, & Higgins, in press; Block, 2007; Spruyt, De Houwer, Everaert, & Hermans, in press).

Finally, we note that our results are difficult to settle with theories of attention stressing that strong selection only occurs when resources are taxed (e.g., Lavie, 1995). One could always argue that every stimulus taxes resources to some degree and hence always some selection exists, but comparing participants' performance for the relevant circle when only one circle out of the two was relevant, and when both were relevant did not uncover any observable effect of load (and hence of the existence of load). Nevertheless, strong selection was clearly demonstrated, providing compelling support to the claim that strong selection can be based on relevance alone regardless of resources limitation.

[4] This value reflects responses to the first probe and was replicated in another similar experiment (7%; complete data available on request). The error rate for the second probe is not reliable as it varies dramatically between the two experiments (32% in this experiment and 7% in the other). Given that the error rate for the first probe is reliable and given that error rates for the first probe were practically identical regardless of whether the inner (7%) or outer (8%) circles were probed, we base our conclusions on the first probe alone.

[5] This pattern of significance does not change if the 2-*SD* filter is not applied.

[6] Note that this is a different account then that of inattentional amnesia (Wolfe, 1999). We argue that this representation was never sufficiently activated, rather than activated ("known") but forgotten. The fact that the effect of relevance is similar regardless of whether the irrelevant stimulus is probed first or second support this account.

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