Psychon Bull Rev (2012) 19:625–630
DOI 10.3758/s13423-012-0252-8

BRIEF REPORT

Reflexive orienting by central arrows: Evidence from the inattentional blindness task

Shai Gabay · Dolev Avni · Avishai Henik

Published online: 17 April 2012

Abstract It was demonstrated that central arrows produce orienting of attention even when they are nonpredictive as to the target location. This finding was suggested to indicate reflexive orienting of attention by central arrows. However, it is not clear whether central arrows can produce an attentional effect without awareness. In two experiments, using a variation of the inattentional blindness task, we examine whether orienting of attention by a central arrow can be demonstrated without conscious perception of the arrow. We found that attention could be directed to the cued location even when the arrow was not consciously perceived.

Keywords Endogenous orienting · Central cues · Inattentional blindness

Introduction

Attention may be oriented voluntarily (endogenous shifts of attention) or captured automatically by an exogenous event. In contrast to exogenous attention, endogenous attention is considered to involve conscious awareness and volitional processes. Endogenous attention is commonly studied using predictive central arrows. Recently, it was demonstrated that central arrows also produce orienting of attention even when they are not predictive as to target location (Hommel & Pratt, 2003; Ristic, Friesen, & Kingstone, 2002; Ristic & Kingstone, 2006). These findings were taken as indications for a reflexive property of central arrows.

S. Gabay (✉) · D. Avni · A. Henik
Department of Psychology and Zlotowski Center for Neuroscience, Ben-Gurion University of the Negev, P.O.B. 653, Beer-Sheva, Israel 84105
e-mail: shaigaba@bgu.ac.il

Several distinctions have been suggested between endogenous and exogenous attention. Endogenous orienting requires resources, which are limited, can easily be suppressed, and is influenced by participants' expectancies. In contrast, exogenous reflexive orienting does not consume resources, cannot be suppressed, and is not affected by participants' expectancies (for a review, see Ruz & Lupiáñez, 2002). In addition, endogenous orienting requires conscious awareness, while exogenous orienting does not (for a review, see Mulckhuyse & Theeuwes, 2010). Because of the suggested automatic nature of endogenous cues, we examined whether attentional orienting by central cues needs to involve conscious perception.

Exogenous and endogenous orienting of attention

When endogenous orienting is to be examined, a predictive central cue is presented before the appearance of a target. The typical pattern of results in this task is a gradually developing validity effect. That is, reaction time (RT) is shorter for valid trials (i.e., target and cue appear at the same location) than for invalid trials (i.e., target and cue appear at opposite locations). When exogenous orienting is to be examined, a nonpredictive peripheral cue is presented before a target. The typical pattern of results is an early validity effect followed by inhibition of return (IOR). That is, RT is shorter for valid trials than for invalid trials at short stimulus onset asynchronies (SOAs; the duration from cue appearance until target appearance) and longer for valid than for invalid trials at longer SOAs (IOR). IOR is commonly achieved with spatially nonpredictive peripheral cues and not with predictive central cues (for a review, see Klein, 2000).

Several differences between exogenous and endogenous orienting have been reported in the literature. There are differences in the time course of the validity effect; that is, endogenous orienting is slower to develop than exogenous orienting. Shepherd and Muller (1989) found that in endogenous orienting, the narrowest focusing of attention was at an SOA of 500 ms. In contrast, they found that exogenous orienting developed a rapid and narrow facilitatory effect, reaching maximal facilitation at an SOA of 50 ms. There are differences in the automaticity of the effects; exogenous orienting is more automatic than endogenous orienting (Jonides, 1981) and can be generated without awareness of the signal triggering it (Danziger, Kingstone, & Rafal, 1998; McCormick, 1997).

Central cues

Several works have demonstrated that meaningful central cues, such as arrows, can produce orienting of attention even when they are not predictive of target location (Hommel & Pratt, 2003; Ristic et al., 2002; Ristic & Kingstone, 2006). These findings suggest that central arrows possess a reflexive property. Similarly, it has been suggested that gaze cues produce reflexive orienting of attention (Friesen & Kingstone, 1998; Kingstone, Friesen, & Gazzaniga, 2000). Because the cues did not predict target location and yet produced orienting of attention, it has been suggested that these cues produce automatic orienting.

The suggestion that central cues have reflexive properties has major implications for the study of attention. Central arrows were used extensively in order to measure endogenous attention (Rafal & Henik, 1994). If, indeed, central arrows contain exogenous properties, the literature regarding endogenous attention should be revised. As has been indicated, the works suggesting that central cues induce reflexive orienting of attention relied on the finding that attention was oriented by central cues even when they were not predictive as to the target location. It should be noted that orienting attention to the location indicated by a nonpredictive cue does not necessarily suggest an automatic process. A stronger test of the automaticity would involve unconscious perception of the cue. It has previously been demonstrated that social cues can trigger orienting of attention even without conscious perception (Sato, Okada, & Toichi, 2007), yet as far as we know, this has never been demonstrated for central arrows. Orienting of attention by an arrow pointing to a specific location, even without participants' conscious awareness, would indicate a truly reflexive property of the arrow. To examine this possibility, we studied effects of arrow cues under inattentional blindness (IB).

Inattentional blindness

In the common paradigm of IB, described by Mack and Rock (1998), participants were presented with a cross and were asked to decide which line, the vertical or the horizontal, was longer. On a critical trial, an object (e.g., a square) was presented next to the cross, and participants were questioned at the end of the block of trials as to whether they had noticed the unusual object. If they had not been aware, they received a second block. Because they performed the primary task in the second block like they did in the first block but were probably also looking for an unusual stimulus, this block was called the *divided attention* block. At the end of it, they were asked again whether an unusual stimulus had appeared during the block. If they had been unaware of the little square, they received a third block. In this block, they were asked not to perform the primary task and only to look at the presentation and to try to notice the critical object. This block was termed a *full attention* block. The surprising finding in this task is that in the first block, in which participants were unaware that an unusual stimulus might appear, a high percentage of participants did not notice the presence of the critical object otherwise easily detected.

Experiment 1

This work was designed to examine whether central arrows can produce attentional orienting even without conscious perception. Participants performed a simple detection task. They were first presented a fixation plus sign, which was followed by a target that appeared in one of two peripheral boxes. On half of the trials, the horizontal line of the fixation plus sign had the shape of an arrow pointing to the left or right (see Fig. 1). On those trials, the target could appear at the location to which the cue was pointing (valid trials) or at the opposite location (invalid trials) with equal probability. On the remaining trials, the fixation was a regular plus sign (neutral trials). Participants were not informed about the arrow, and 60 % of participants reported that they had not noticed it after the experimental block ended. If orienting of attention is automatically modulated by central arrows, attentional effects should be present even when participants are not aware of the arrow.

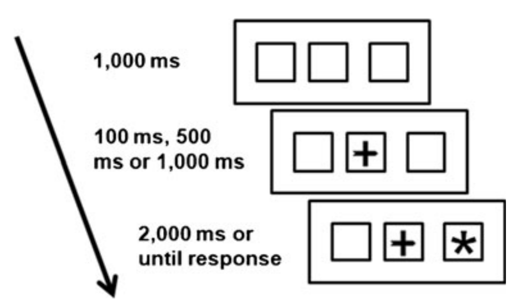

Fig. 1 A typical sequence of events in the inattentional blindness block

Method

Participants Thirty participants from Ben-Gurion University of the Negev participated in the experiment in exchange for course credit. All participants had normal or corrected-to-normal vision.

Apparatus and stimuli The stimuli were white figures, on a black background, consisting of three square boxes (2 ° each side), one at the center of the screen, and the centers of the other two were 7.5 ° from the center of the screen. A fixation plus sign (1 °) was presented first at the center of the central box. On half of the trials, the horizontal line of the fixation plus sign resembled an arrow pointing to the left or right of fixation. Next, a target asterisk (1 °) appeared in the center of one of the peripheral boxes. Participants responded to the target by pressing the space bar of a keyboard with their dominant hand. Each participant was presented with 160 trials, of which 16 were catch trials with no target. The experimental trials were presented in two experimental blocks, each containing 80 trials. Each block contained three different SOAs (100, 500, and 1,000 ms). Prior to the experimental blocks, participants performed 4 practice trials without an arrow appearing at fixation.

Procedure Participants were tested in a dimly illuminated room. They were seated 57 cm from the computer monitor. Participants were instructed to maintain fixation on the plus sign throughout the experiment. The experimenter monitored participants' eye movements through a JVC-TK240 video camera. If an eye movement was detected, the experimenter sent an alerting sound to the participant. The participants were instructed to press the space bar as quickly as possible when the asterisk appeared. Participants were not informed regarding the possible appearance of an arrow embedded in the fixation plus sign. The arrow was not predictive as to target location. Each trial began with the appearance of three horizontally aligned boxes. After 1,000 ms, a fixation plus sign appeared and remained in view throughout the trial. On half of the trials, an arrow was presented as the horizontal line of the fixation sign. After a variable SOA (100, 500, or 1,000 ms) from the appearance of the fixation, a target appeared for 2,000 ms or until the participant's response. After completing the experimental block, participants were asked whether they had noticed a change in any stimulus shape during the experimental trials. If participants responded *yes*, they were asked what stimuli had changed and what the change was. For participants who noticed the arrows, the experiment ended. Those who did not notice the arrow preformed an additional 16 trials of the task. After those trials, all the participants noticed the arrow. Participants who detected the arrows only after the additional block were asked again whether they had not noticed the arrow during the first experimental block. All replied that they had not.

Results

Eighteen participants did not notice the central arrow, and 12 participants did. Trials on which responding was very fast (less than 100 ms) or very slow (more than 1,500 ms) were excluded from the analysis. These trials accounted for less than 1 % of the data.

RT as a function of SOA, arrow validity, and participants' perception is presented in Fig. 2. An analysis of variance (ANOVA) with SOA (100, 500, 1,000 ms), arrow validity (valid, invalid, neutral), and participant's perception (perceived, not perceived) as factors revealed a significant main effect of SOA, $F(2, 56) = 54$, $MSE = 1{,}056$, $p < .001$, reflecting a decline in RT at the longer SOAs. The main effect of validity was also significant, $F(2, 56) = 9.4$, $MSE = 339$, $p < .001$. Further analyses of this effect revealed a significant difference between valid and invalid trials, $F(1, 28) = 15.6$, $MSE = 408$, $p < .001$, and between invalid and neutral trials, $F(1, 28) = 7.2$, $MSE = 225$, $p < .05$. Importantly, the validity × participant's perception interaction was not significant, $F = 2.6$. Both participants' perception groups demonstrated a significant validity effect (as indicated by comparing valid and invalid conditions) [$F(1, 28) = 9.5$, $MSE = 408$, $p < .01$, and $F(1, 28) = 6.1$, $MSE = 408$, $p < .05$, for the perceived and not-perceived groups, respectively]. This indicates that both the perceived and not-perceived groups demonstrated a significant validity effect. None of the other effects or interactions were significant ($F < 1$ for all).

These findings indicate that arrow cues produce reflexive orienting of attention even without conscious perception of the arrow.

Discussion

In this experiment, we examined the reflexive nature of central cues. We demonstrated that central arrows produced orienting of attention even when they were not perceived consciously by the participants. This fits with suggestions that nonpredictive central arrows can produce automatic orienting of attention (Hommel & Pratt, 2003; Ristic et al., 2002; Ristic & Kingstone, 2006). Our work demonstrates that similar to exogenous orienting, conscious awareness is not necessary in order to produce orienting of attention by a central arrow.

Experiment 2

It should be noted that in the first experiment, participants were asked to report whether they had noticed the IB object.

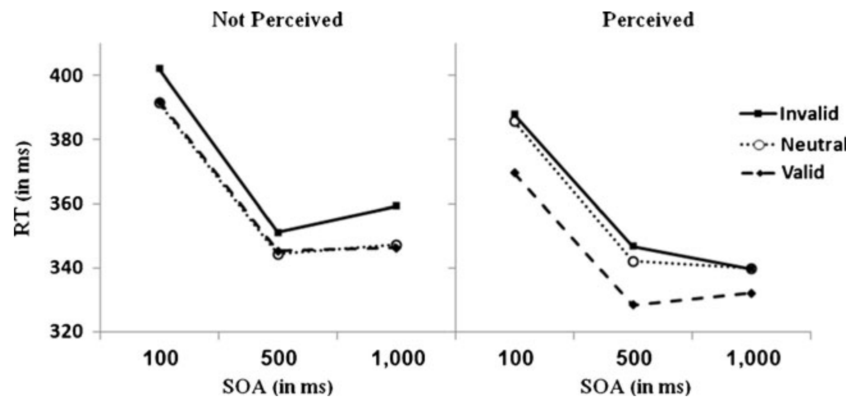

Fig. 2 Experiment 1: Reaction time (RT) as a function of stimulus onset asynchrony (SOA), arrow validity, and participants' perception

It is possible that participants were unsure of themselves in reporting the existence of the IB object. In order to have a stronger claim for the lack of conscious perception of the IB object, in Experiment 2 participants were asked to choose which one of six possible fixation objects had appeared. If participants were unable to indicate or guess which was the IB object, we would have more confidence that the IB object was not consciously perceived.

Method

Participants Twenty-three participants from Ben-Gurion University of the Negev participated in the experiment in exchange for course credit. All participants had normal or corrected-to-normal vision.

Apparatus and stimuli All stimuli were identical to those in the first experiment.

Procedure The procedure was identical to that of the first experiment. After completing the experimental block, participants were asked whether they had noticed a change in any stimulus shape during the experimental trials. If participants responded *yes*, they were asked what stimuli had changed and what the change was. For participants who noticed the arrows, the experiment ended. Those who had not noticed the arrows were presented with six possible fixations (see Fig. 3). Participants were told that one of the six fixation objects had been presented interleaved with a regular fixation during the experiment. They were asked to choose which of the fixations had appeared in their task. If they were not able to choose, they were asked to guess.

Results

Ten participants did not notice the central arrow, and 13 participants did. Trials on which responding was very fast (less than 100 ms) or very slow (more than 1,500 ms) were excluded from the analysis. These trials accounted for less than 1 % of the data. Only 1 participant from the group that did not notice the central arrow guessed correctly which type of fixation was presented during the task. This is lower than chance level and strengthens our conclusion that in the not-perceived group, the arrow was not consciously perceived.

RT as a function of SOA, arrow validity, and participants' perception is presented in Fig. 4. An ANOVA with SOA (100, 500, 1,000 ms), arrow validity (valid, invalid, neutral), and participant's perception (perceived, not perceived) as factors revealed a significant main effect of SOA, $F(2, 42) = 47$, $MSE = 728$, $p < .001$, reflecting a decline in RT at the longer SOAs. The main effect of validity was also significant, $F(2, 42) = 8.8$, $MSE = 559$, $p < .001$, as a result of longer RTs for invalid than for valid cues. Further analyses of this effect revealed a significant difference between valid and invalid trials, $F(1, 21) = 14.9$, $MSE = 610$, $p < .001$. A significant difference was also found when invalid and neutral conditions were compared, $F(1, 21) = 8.5$, $MSE = 610$, $p < .01$.

Importantly, as in the first experiment, the validity × participant's perception interaction was far from significant,

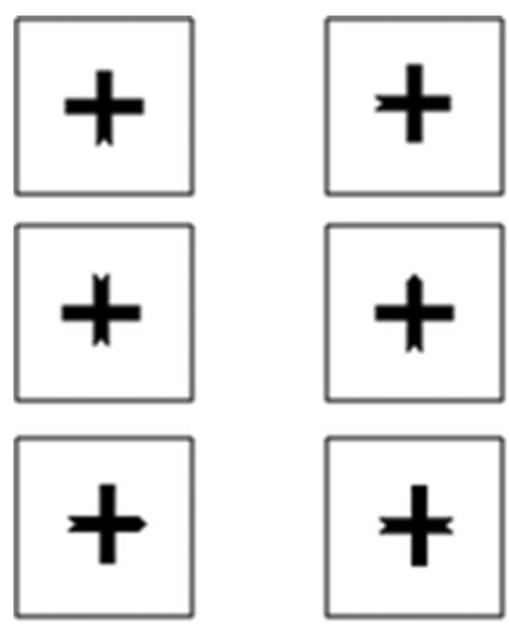

Fig. 3 Six fixation options presented during the recognition task

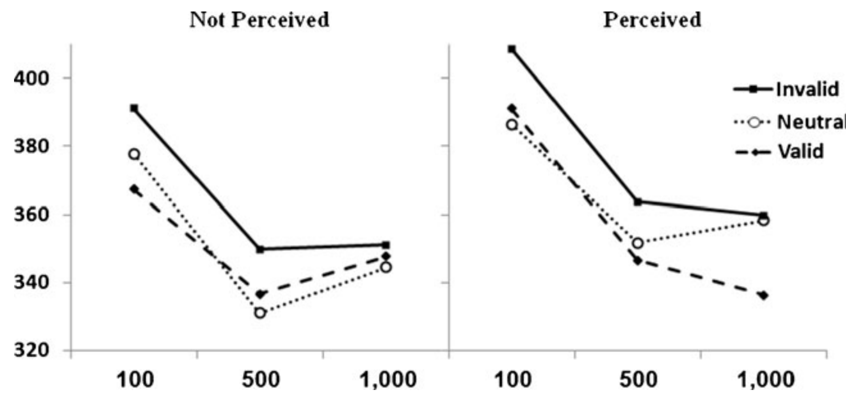

Fig. 4 Experiment 2: Reaction time (RT) as a function of stimulus onset asynchrony (SOA), arrow validity, and participants' perception

$F = 1.4$. Both participants' perception groups demonstrated a significant validity effect [$F(1, 21) = 11.9$, $MSE = 610$, $p < .01$, and $F(1, 21) = 4.4$, $MSE = 610$, $p < .05$, for the perceived and not-perceived groups, respectively].

Discussion

In the second experiment, participants who reported not perceiving the IB fixation could not recognize it out of six possible stimuli. This strengthens our suggestion that those participants did not consciously perceive the IB object. Yet they still presented a significant validity effect for the direction of the arrow.

General discussion

In two experiments, it was demonstrated that central arrows can produce orienting of attention even without conscious perception of the arrow. This strongly supports the suggestion that central arrows produce reflexive attentional shifts (Hommel & Pratt, 2003; Ristic et al., 2002; Ristic & Kingstone, 2006).

Methodological issues

There are several differences between the IB task we used and the typical IB task presented by Mack and Rock (1998). First, in the original task, the IB object was presented only once during the experimental block. In accordance with Moore and Egeth (1997), we used a longer version of the IB paradigm in which the IB object appeared on 50 % of the trials throughout the block. This allowed measuring the IB object's influence on participants' performance without the need for a large number of participants. The inquiry about the perception of the IB object was conducted after the IB block ended. Second, typically, the IB object is presented only for a brief duration (e.g., 200 ms). As in the work of Most, Scholl, Clifford, and Simons (2005), we used a long presentation of the IB object. This reduced the chances for alternative explanations for our findings, such as failure to remember the IB object. Lastly, in typical IB tasks, participants do not gaze directly at the IB object. Our IB object was presented at the center of gaze. Participants were instructed to fixate the fixation plus sign, which contained the IB arrow, and yet many participants failed to notice it.

Automaticity of central arrows

Eimer and Schlaghecken (2002) demonstrated that in an arrow discrimination task, masked prime arrows that were not consciously perceived produced response inhibition. Our study used a simple detection task in which only one response key was used, and we found facilitation. Since different responses were not used in our task, it is reasonable to assume that the pattern of results observed in our work is a consequence of attentional orienting rather than response bias.

Ruz and Lupiáñez (2002) suggested that for reflexive orienting, mental sets related to the task at hand are most influential in modulating attentional capture. In accordance with these researchers, Lichtenstein-Vidne, Henik, and Safadi (2007) demonstrated that the direction of distracting arrows influenced performance only when it was task relevant. They also demonstrated that arrow directions appearing at the center of attention influenced performance regardless of task relevance (third experiment). The influence of the distracting arrow position (central vs. peripheral) on performance in Lichtenstein-Vidne et al.'s work and the fact that, in the present work, central arrows produced orienting of attention even without conscious perception might indicate that spatial attention may be important for the influence of task-irrelevant stimuli on performance. Naccache, Blandin, and Dehaene (2002) demonstrated that allocation of temporal attention is essential for occurrence of the unconscious priming effect. Future work should examine the effect of unconscious peripheral arrows on performance to unravel the role of spatial attention in the influence of unconscious stimuli on performance.

The present results fit with previous works demonstrating that central arrows produce orienting of attention even when they are not predictive of target location (Hommel & Pratt, 2003; Ristic et al., 2002; Ristic & Kingstone, 2006). These findings fulfill one description for exogenous cues by demonstrating an attentional effect regardless of participants' expectancies (for a review, see Ruz & Lupiáñez, 2002). However, this criterion is not sufficient in order to regard the orienting of attention by central arrows as reflexive. Exogenous reflexive orienting of attention does not require conscious awareness in order to produce orienting of attention. This is the strongest criterion for reflexive orienting. It was previously demonstrated that peripheral cues can generate orienting of attention without awareness (Danziger et al., 1998; McCormick, 1997). This was also demonstrated for social cues (Sato et al., 2007). The present work demonstrates this for central arrows and provides a strong indication of their reflexive property. It is worth noting that in light of the results reported by Lichtenstein-Vidne and colleagues (2007), it is possible that the present conclusion may hold only for central arrows and not for arrows presented elsewhere in the field of vision.

References

Danziger, S., Kingstone, A., & Rafal, R. (1998). Orienting to extinguished signals in hemispatial neglect. *Psychological Science, 9,* 119–123.

Eimer, M., & Schlaghecken, F. (2002). Links between conscious awareness and response inhibition: Evidence from masked priming. *Psychonomic Bulletin & Review, 9,* 514–520.

Friesen, C. K., & Kingstone, A. (1998). The eyes have it! Reflexive orienting is triggered by nonpredictive gaze. *Psychonomic Bulletin & Review, 5,* 490–495.

Hommel, B., & Pratt, J. (2003). Symbolic control of visual attention: The role of working memory and attentional control settings. *Journal of Experimental Psychology. Human Perception and Performance, 29,* 835–845.

Jonides, J. (1981). Voluntary vs. automatic control over the mind's eye's movement. In J. B. Long & A. D. Baddeley (Eds.), *Attention and performance IX* (pp. 187–203). Hillsdale, NJ: Erlbaum.

Kingstone, A., Friesen, C. K., & Gazzaniga, M. S. (2000). Reflexive joint attention depends on lateralized cortical connections. *Psychological Science, 11,* 159–166.

Klein, R. (2000). Inhibition of return. *Trends in Cognitive Sciences, 4,* 138–146.

Lichtenstein-Vidne, L., Henik, A., & Safadi, Z. (2007). Task-relevance modulates the effects of peripheral distracters. *Quarterly Journal of Experimental Psychology, 60,* 1216–1226.

Mack, A., & Rock, I. (1998). *Inattentional blindness*. Cambridge, MA: MIT Press.

McCormick, P. A. (1997). Orienting attention without awareness. *Journal of Experimental Psychology. Human Perception and Performance, 23,* 168–180.

Moore, C., & Egeth, H. (1997). Perception without attention: Evidence of grouping under conditions of inattention. *Journal of Experimental Psychology. Human Perception and Performance, 23,* 339–352.

Most, M. B., Scholl, B. J., Clifford, E. R., & Simons, D. J. (2005). What you see is what you set: Sustained inattentional blindness and the capture of awareness. *Psychological Review, 112,* 217–242.

Mulckhuyse, M., & Theeuwes, J. (2010). Unconscious attentional orienting to exogenous cues: A review of the literature. *Acta Psychologica, 134,* 299–309.

Naccache, L., Blandin, E., & Dehaene, S. (2002). Unconscious masked priming depends on temporal attention. *Psychological Science, 13,* 416–424.

Rafal, R., & Henik, A. (1994). The neurology of inhibition: Integrating controlled and automatic processes. In D. Dagenbach & T. H. Carr (Eds.), *Inhibitory processes in attention, memory, and language* (pp. 1–51). San Diego, CA: Academic Press.

Ristic, J., Friesen, C. K., & Kingstone, A. (2002). Are eyes special? It depends on how you look at it. *Psychonomic Bulletin & Review, 9,* 507–513.

Ristic, J., & Kingstone, A. (2006). Attention to arrows: Pointing to a new direction. *Quarterly Journal of Experimental Psychology, 59,* 1921–1930.

Ruz, M., & Lupiáñez, J. (2002). A review of attentional capture: On its automaticity and sensitivity to endogenous control. *Psicologica, 23,* 283–309.

Sato, W., Okada, T., & Toichi, M. (2007). Attentional shift by gaze is triggered without awareness. *Experimental Brain Research, 183,* 87–94.

Shepherd, M., & Muller, H. J. (1989). Movement versus focusing of visual attention. *Perception & Psychophysics, 46,* 146–154.