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Cognition 106 (2008) 1478–1486
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Brief article

The effects of expectancy on inhibition of return

Shai Gabay *, Avishai Henik

Department of Psychology and Zlotowski Center for Neuroscience, Ben-Gurion University of the Negev, Beer-Sheva, Israel

Received 1 May 2006; revised 13 May 2007; accepted 18 May 2007

Abstract

This research examined the influence of cue temporal predictability on inhibition of return (IOR). In exogenous attention experiments, the cue that summons attention is non-informative as to where the target will appear. However, it is predictive as to when it will appear. Because in most experiments there are equal numbers of trials for each cue–target interval (SOA – stimulus onset asynchrony), as time passes from the appearance of the cue, the probability of target presentation increases. Predictability was manipulated by using three SOA distributions: non-aging, aging and accelerated-aging. A robust IOR was found that was not modulated by temporal information within a trial. These results show that reflexive effects are relatively protected against modulation by higher volitional processes.

Keywords: Expectancy; IOR; Non-aging distributions; Spatial attention; Temporal predictability

1. Introduction

In the process of evolutionary development, we started as simple creatures that were very dependent on reflexes and automatic processes in order to survive. As we evolved we developed voluntary control over our basic processes. A similar pro-

* Corresponding author. Tel.: +972 8 6418636; fax: +972 8 6472072.
E-mail address: shaigaba@bgu.ac.il (S. Gabay).

doi:10.1016/j.cognition.2007.05.007

cess is manifested in a child's development. We are born as a bundle of reflexes and as we mature, primitive reflexes are inhibited and our behavior is guided by more volitional goals (Rafal & Henik, 1994). This work examines one of these intriguing interactions between a primitive and automatic process (inhibition of return – IOR) and a volitional process (expectancy). Herein, we study the influence of participants' temporal expectancy on the IOR effect. The IOR effect is a reflexive and automatic process, and in contrast to recent works, we suggest that it is not modulated by volitional control.

The typical pattern of results in the exogenous spatial cueing paradigm (Posner & Cohen, 1984) is an early validity effect followed by IOR. That is, reaction time (RT) for valid trials (i.e., target and cue appear at the same location) is faster than for invalid trials (i.e., target and cue appear at opposite locations) at short SOAs, and slower for valid than invalid trials at longer SOAs. IOR is achieved with spatially non-predictive exogenous cues and not with predictive endogenous cues (Klein, 2000). IOR is considered to be a very basic and reflexive effect that enables an efficient scanning of the environment (Klein, 2000). In order to scan our environment efficiently, it is preferable not to go back to scanned locations but to move to new areas in the field. IOR improves scanning efficiency by providing a mechanism that prevents returning to already scanned locations (Klein & MacInnes, 1999; Posner & Cohen, 1984).

Evidence for the reflexive nature of IOR comes from several works showing that a voluntary shift of attention does not interact with a reflexive exogenous shift of attention (Berger, Henik, & Rafal, 2005; Berlucchi, Chelazzi, & Tassinari, 2000). In contrast, several researchers suggested that capture of attention by an exogenous cue can be modulated by volitional processes. Yantis and Jonides (1990) showed that predictiveness of an endogenous cue can modulate the capture of attention by an exogenous onset of a distracter. In a review paper, Ruz and Lupianez (2002) suggested that automaticity of the exogenous attentional system can be seen as the "default" mode of the attentional system. They argued that a variety of experimental procedures produced evidence that attentional allocation can be modulated by volitional control and task demands.

Several reports have indicated the involvement of the superior colliculus (SC) in IOR (Berger & Henik, 2000; Rafal, Calabresi, Brennan, & Sciolto, 1989; Ro, Shelton, Lee, & Chang, 2004). The most direct evidence for the connection between the SC and IOR was provided by a unique patient with a hemorrhage in the right SC, who showed a normal IOR in the hemifield projecting to the intact SC, but no IOR in the hemifield projecting to the damaged SC (Sapir, Soroker, Berger, & Henik, 1999). SC is a sub-cortical structure, but it is influenced by higher cortical areas that could modulate its activity (Corbetta & Shulman, 2002; Hunt, Olk, Von Muhlenen, & Kingstone, 2004; Sapir, Hayes, Henik, Danziger, & Rafal, 2004).

IOR is frequently produced by an exogenous non-predictive cue. Commonly, a flash of light in the periphery is employed as a cue that appears before the target. This cue does not predict target location. For example, a cue on the right can be followed by a target on the left or on the right with the same probability. Recently, a specific debate has focused on whether temporal information can modulate IOR. In most experiments, RT decreases as SOA increases. The decrease of RT with longer SOAs may indicate the participant's anticipation of the target's appearance. That is, although the cue does not convey spatial information, it does provide temporal information. This is due to the fact that the objective probability of a target's appearance increases with SOA. A recent work has indicated that the spatial and temporal inhibitory processes are additive and do not influence each other (Los, 2004). In contrast, previous experiments suggested that IOR can be modulated by manipulating temporal predictability of the cue (Milliken, Lopianz, Roberts, & Stevanovsky, 2003; Mondor, 1999). Recently, Tipper and Kingstone (2005) manipulated expectancy by increasing the percentage of trials in which the target did not appear (catch trials) in an exogenous cueing experiment. They found that a high percentage of catch trials (25%) eliminated the decline in RT as the SOA increased and reduced IOR. The authors claimed this indicated that participants did not use the cue as a signal to prepare for target appearance. Yet, proportion of catch trials also modulated general RT. That is, the experimental group (with 25% catch trials) was much slower than the control groups, which may be an indication for a change in alertness. Naatanen (1972) showed that the number of catch trials has a linear influence on RT such that adding catch trials slows responding. He offered three possible explanations for the influence of increased catch trials on RT: (1) lower expectancy – the objective probability of target appearance is reduced, (2) punishment effect – target absence when the participant anticipates the target may have a "punishing" effect on the participant, and (3) greater exhaustion – in a catch trial, the participant needs to sustain a high readiness to react. At least two of these possible explanations can influence alertness. If the participant's expectancy for a target (not for the time of target appearance) is lower or if he is more exhausted than in other conditions, it might influence his alertness. Posner and Boies (1971) demonstrated that the influence of alertness is most pronounced after a 500 ms cue–target interval. Accordingly, if participants in Tipper and Kingstone's (2005) experimental groups were not as alert as the controls, the difference between the groups should be manifested at the later SOAs. Fernandez-Duque and Posner (1997) examined the relations between orienting and alerting mechanisms. Examination of their Fig. 2 suggests alertness modulated general RT. Namely, in the high alertness condition, the relationship between RT and SOA was steeper than in the low alertness condition. Moreover, recently Callejas, Lupiàñez, and Tudela (2005) showed that the time course of orienting could be accelerated under conditions of high alertness. This interaction between the alerting and orienting networks can account for Tipper and Kingstone's (2005) results. In order to bypass these difficulties we employed Naatanen's (1970) suggestion of creating non-aging fore-periods.

2. The current work

In the common cueing experiment, all SOAs are equally likely, so that the probability of target appearance increases as SOA increases (changes in probabil-

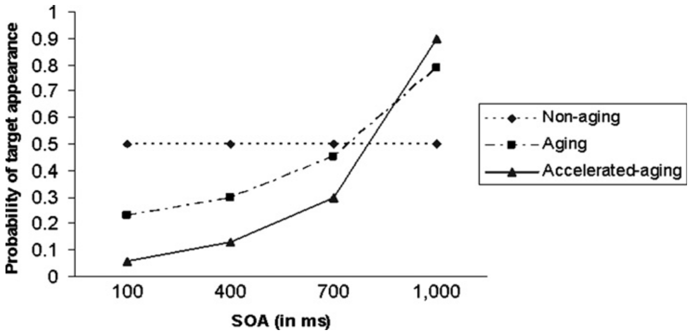

Fig. 1. Changes in probability of target appearance as a function of SOA and trial distribution.

ity of target appearance are depicted in Fig. 1). For example, in a block with 4 SOAs and 256 trials, 16 of which are catch trials, 60 trials would be assigned to each SOA. The probability of target appearance in the first SOA is 60 divided by the total number of trials (256), which is 0.23. After the first no-target SOA, the probability of target appearance at the second SOA is 60 divided by the total number of trials minus 60 (i.e., trials assigned to the first SOA) – 196; this probability equals 0.3. Similarly, the probability of target appearance at the third SOA will be 0.44, and in the last SOA the probability of target appearance will be 0.79. This acceleration in the probability of target appearance as SOA increases makes the cue predictive regarding when the target will appear. In contrast, the non-aging distribution maintains a constant 50% chance that the target will appear at any given SOA. In the current experiment, the first SOA was assigned half of the trials (128) so that the probability of target appearance was 0.5. The second SOA was assigned half of the remaining trials (64), so that the probability of target appearance remained 0.5, and so on for the third and fourth SOAs. This constant probability of target appearance throughout the different SOAs makes the cue non-informative as to when the target will appear. In addition to the non-aging condition we used an accelerated-aging condition, which was the reverse of the non-aging condition (Baumeister & Joubert, 1969). This condition is characterized by an accelerated probability of target appearance as SOA increases. In the first SOA target probability was 0.06, in the second SOA it was 0.13, in the third, 0.3, and in the fourth, 0.9. Hence, this arrangement made the cue more informative as to when the target would appear compared with the other conditions.

Naatanen (1970) has shown that by using a non-aging fore-period design, the effect of the decline in RT with fore-period increase can be eliminated. This finding can be attributed to the disappearance of the participants' expectancy as to when the target will appear. The current design enables to examine whether expectancy, a volitional process, can influence IOR, a reflexive–automatic phenomenon. The current experimental design overcomes a potential confound that might have influenced Tipper and Kingstone's (2005) results.

3. Method

3.1. Participants

Thirty participants from Ben-Gurion University of the Negev participated in the experiment in exchange for course credit. Participants were randomly assigned to one of three experimental groups – aging fore-period, non-aging fore-period or accelerated-aging fore-period.

3.2. Apparatus and stimuli

The stimuli were white figures, on a black background, consisting of a fixation dot (0.3°) at the center of the computer screen, and three square boxes (2.5° each side), one at the center of the screen, and the center of the other two were 6.5° from the center of the screen. A target letter "X" (1.3°) appeared in the center of one of the peripheral boxes. The target letter was preceded by a brightening of one of the two peripheral boxes, which was accomplished by widening the box's contour from 1 to 5 mm. Participants responded to the target letter by pressing the space bar of a keyboard with their dominant hand.

3.3. 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 fixation point 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 alert sound to the participant. The participants were instructed to press the space bar as fast as possible when the "X" appeared, but to avoid false responses. They were also informed that the peripheral cue was not informative as to where the target would appear. Each trial began with the appearance of the fixation dot for 500 ms. After 400 ms, one of two peripheral boxes brightened for 75 ms (the cue). One hundred milliseconds, 400 ms, 700 ms or 1000 ms after the appearance of the cue, the target "X" appeared in one of the peripheral boxes and remained in view until the participant responded. In 6 percent of the trials no target appeared (i.e., a catch trial) and the participant was instructed not to respond. Each participant had eight practice trials before the experiment began. Participants were assigned to one of three experimental groups: (1) an aging fore-period group, in which the different SOAs were equally likely, (2) a non-aging fore-period group, in which for all SOAs there was a 50% chance that the target would appear, and (3) an accelerated-aging fore-period group, which had conditions opposite (i.e., a reversed distribution of SOAs) of the non-aging fore-period group.

The experiment was divided to four blocks, of 256 trials (a total of 1024 trials per participant). See Table 1 for the SOA distribution for each experimental group.

Table 1
The distribution of trials for each SOA and experimental group in a single block

SOA (ms)	Non-aging fore-period	Aging fore-period	Accelerated-aging fore-period
100	128	60	16
400	64	60	32
700	32	60	64
1000	16	60	128
Catch trials	16	16	16

4. Results

Trials in which the participants responded very fast ($\geqslant 100$ ms) or very slow ($\leqslant 1000$ ms) were excluded from the analysis. These trials accounted for 2% of the data. RT as a function of cue validity and SOA for every experimental group is presented in Fig. 2. Participants responded to 3% of the catch trials.

As can be seen, the pattern of results fits the hypothesis that SOA distribution can influence expectancy of the participants. In the non-aging fore-period group, RT does not change with SOAs, whereas in the aging fore-period group and the accelerated-aging group, RTs decrease as SOAs increase. An analysis of variance (ANOVA) with group (non-aging, aging, accelerated-aging), SOA (100 ms, 400 ms, 700 ms, 1000 ms) and validity (valid, invalid) confirmed this observation. There was a significant interaction of SOA × group [$F(6,81) = 11.4$, $p < .001$]. This interaction was further analyzed through an interaction between comparisons that examined the non-aging group linear trend to the aging group linear trend. This comparison was significant [$F(1,18) = 13.4$, $p < .01$]. A comparison of the linear trend of the aging and the accelerated-aging groups also produced a significant effect [$F(1,18) = 6.62$, $p < .05$]. These results indicate that the experimental manipulation did influence participants' expectancy. We examined the linear trend only in the non-aging group. The analysis produced a non-significant effect [$F < 1$], which indicates that there was no influence of expectancy on participant's RT. In contrast, the linear trend of the aging group was significant [$F(1,9) = 17.51$,

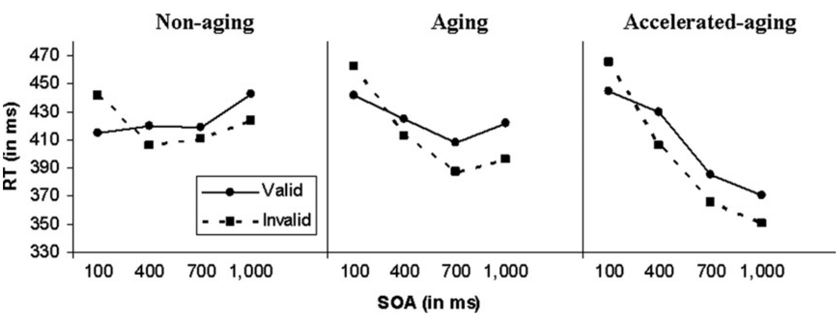

Fig. 2. RT as a function of SOA, validity and group.

$p < .01$] and the same was true for the accelerated-aging group [$F(1,9) = 32.37$, $p < .001$]. Namely, RT as a function of SOA in the non-aging group was flat, whereas, RT changed as a function of SOA in the other two groups and had the steepest curve for the accelerated-aging group. The validity × SOA interaction was also significant [$F(3,81) = 39.59$, $p < .001$]. This was due to an early validity effect at SOA 100 ms and an IOR at the three long SOAs [$F(1,27) = 67.16$, $p < .001$] (see Fig. 2).

The triple interaction between SOA × validity × group was not significant. In spite of this, due to the theoretical importance of this interaction, we further analyzed this triple interaction in order to determine if IOR was modulated by group. We compared the validity effect in the averaged last three SOAs in the non-aging fore-period group with the validity effect in the same averaged SOAs in the aging group. This comparison, which is similar to the one performed by Tipper and Kingstone (2005), was not significant [$F < 1$]. In addition, the same comparison of the last three SOAs in the aging fore-period group with the accelerated-aging group was also not significant [$F < 1$]. These analyses indicate that IOR was not modulated by the experimental condition.

5. Discussion

We found elongation of SOA reduced RT when the cue was temporally predictive (aging condition) but not when it was not predictive (non-aging). Accordingly, we conclude that the manipulation of SOA distribution modulated participants' expectancy. The slope of the RT curve as a function of SOA was steepest for the accelerated-aging, less steep for the aging and shallow for the non-aging group. However, these differences in slope, which are indications for differences in expectancy (Tipper & Kingstone, 2005), did not modulate IOR.

In this work, we eliminated participant's expectancy by using a non-aging distribution of SOAs. We believe it is important for researchers employing different trial intervals to be aware of the influence of expectancy on results. An equal distribution of trials exerts an influence of temporal expectancy that might influence participants' performance.

Tipper and Kingstone (2005) reported a reduction in IOR and that RT as a function of SOA was shallower for a condition with a high percentage of catch trials than for one with a low percentage of catch trials. Examination of the graphs in Tipper and Kingstone's study suggests that general RT in the experimental group was higher than in any other group. Hence, it is possible that the change in IOR was a consequence of a change in alertness, which has been shown to change the time course of the orienting network (Callejas et al., 2005), and RT as a function of SOA (Fernandez-Duque & Posner, 1997; Posner & Boies, 1971), rather than a consequence of expectancy for target appearance.

In contrast to Tipper and Kingstone's (2005) suggestion, we showed IOR was not modulated by temporal expectancy. Our non-aging fore-period group was presented with conditions devoid of cue temporal predictability, whereas the aging fore-period group was presented with similar (in temporal predictability) conditions to the typical experiment in the field. Nevertheless, *IOR was comparable in all conditions*. Hence, our work fits with the view of IOR as a reflexive phenomenon. This is an example where volitional processes did not modulate an automatic effect. Note however, Tipper and Kingstone's experiment, the current experiment, and numerous other attention orienting experiments use target detection. It has been suggested that detection, being a simple task, may not recruit higher processes (Egly & Homa, 1991). Accordingly, IOR may be eliminated (Terry, Valdes, & Neill, 1994) or delayed (Lupianez, Milan, Tornay, Madrid, & Tudela, 1997) with discrimination tasks. Milliken et al. (2003) demonstrated that in a discrimination task IOR can be modulated by temporal expectancy. We suggest that in very simple tasks not requiring deep processing of the target, reflexive processes are not modulated by volitional processes and as task demands increase, more endogenous control will be manifested. Moreover, we examined our results and those reported by Tipper and Kingstone in light of the literature on alertness and the relationship between alertness and orienting of attention. This led us to suggest that alertness may modulate IOR. A direct examination of this conjecture is warranted and we are currently engaged in appropriate experiments.

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