Acta Psychologica 221 (2021) 103439

Contents lists available at ScienceDirect

Acta Psychologica

journal homepage: www.elsevier.com/locate/actpsy

Does temperament have a differential effect on *Inhibition of Return* (IOR)?

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ARTICLE INFO

Keywords:
Inhibition of return
Temperament
Orienting of attention
Cueing task
Saccadic movements

ABSTRACT

Reaction times to targets presented at previously stimulated locations are longer after some time (approx. 300 ms) than to targets presented in new locations. This effect is widely known as *Inhibition of Return* (IOR). It is typically explained in terms of an inhibitory bias against returning attention to places previously attended to and thus promoting attentional activity elsewhere. Regardless of its attentional character, IOR seems to encapsulate the interaction between two fundamental dimensions of temperament: engaging in versus inhibition and withdrawal from activity. Approaching IOR in this perspective, the question has arisen as to whether individual differences in reactivity as a temperamental trait express themselves in the time course and magnitude of this effect. 90 subjects (30 low, 30 medium and 30 highly reactive individuals) participated in the study. To the best of our knowledge, there are no other studies of individual differences in these parameters of IOR that use saccadic responses to measure its effect on behavior. The results show that in individuals who are higher in terms of their reactivity, IOR starts earlier and continues at the following SOAs but its magnitude is smaller than in less reactive individuals. The results are explained and discussed in light of the Regulative Theory of Temperament. This is the final version of the Abstract which has been accepted in the revised manuscript.

1. Introduction

The onset of a peripheral visual stimulus results reflexively in faster and more accurate responses to targets in a location where the stimulus was presented than in the other locations. However, when the time interval between the stimulus and the target exceeds approximately 300 ms, the reverse effect occurs, with slower and less accurate reactions to targets appearing at recently cued locations. This phenomenon was discovered independently by Posner and Cohen (1984) as well as by Tassinari, Aglioti, Chelazzi, Marzi, and Berlucchi (1987) and has been referred to variously as "inhibitory aftereffect" (Tassinari et al., 1987), "inhibitory tagging" (Fuentes, Vivas, & Humphreys, 1999; Klein, 1988) and, most frequently, "inhibition of return" (IOR; Posner, Rafal, Choate, & Vaughan, 1985). It is typically explained in terms of an inhibitory bias against returning attention to previously attended locations, directing it instead toward other locations and, thus, to serve as a novelty seeking mechanism (Posner & Cohen, 1984) or as a foraging facilitator (Klein & MacInnes, 1999; Itti & Koch, 2001). According to what might be called the "disengagement hypothesis" (Klein, 2000; Klein, 2004), based on an idea already proposed by Posner and Cohen (1984), attentional capture and IOR are two parallel processes. Initially, the inhibitory effect of IOR is overshadowed by the facilitative effect of attentional capture. IOR is revealed in performance only as attention is disengaged from the cue and facilitation wanes.

There are a variety of factors affecting the reciprocal dynamics between the facilitative effect of attentional capture and the IOR effect which result in the time course of IOR's appearance (Lupiáñez, Klein, & Bartolomeo, 2006; Mishra, Hilchey, Singh, & Klein, 2012). It may also be due to individual differences. As already noted by Klein (2005), in young children, the elderly or people suffering from schizophrenia, IOR does not appear or is delayed in comparison to control individuals. Klein (2004) suggests that the results might be explained by decreased executive control over attentional disengagement from the uninformative cue.

The research on the conditions which may have a differential effect on IOR and other cases of attentional control continues, although with ambiguous results. They may be generally contextualized as fitting into the classical conceptual framework of the interplay between personality/temperament and regulatory processes (Rothbart & Derryberry, 1981), e.g., executive attention, (Rothbart & Posner, 1985). Wilson, Lowe, Ruppel, Pratt, and Ferber (2016), for example, sought to relate the characteristics of IOR to the Big Five traits and their findings suggest that

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https://doi.org/10.1016/j.actpsy.2021.103439
Received 23 May 2021; Received in revised form 15 October 2021; Accepted 21 October 2021
Available online 23 October 2021

individuals high in Conscientiousness show IOR in a small area around the cue/target location while those high in Openness exhibit more widespread IOR. Earlier, Avila (1995) showed the stronger effect of IOR in anxious and neurotic subjects which may suggest that their control system tends to narrow the scope of attentional activity. However, focusing on a relationship between heightened anxiety and impaired inhibitory control, although with the use of an anti-saccade task, Myles, Grafton, and MacLeod (2020) demonstrated that the induction of a state of anxiety in high trait anxious participants results in reduced inhibitory control and, on the other hand, that inhibitory control training procedures can serve to reduce dispositional anxiety in highly anxious individuals. Also, Morriss and McSorley (2019) showed reduced attentional inhibition in individuals high in intolerance of uncertainty but in the absence of a direct threat.

There is also a body of research on individual differences in the dynamics of IOR across the field of clinical psychology addressing the question of emotion regulation disorders in cases like phobias, depression, autism etc. Berdica, Gerdes, Pittig, and Alpers (2014), for example, investigated the effect of IOR using a discrimination task with phobia-related stimuli. The results revealed a strong IOR effect in saccadic responses independent of stimulus category and diagnostic group. However, a psychophysiological study of depressed patients by Dai and Feng (2009) shows reduced IOR when the cues took the form of angry and sad faces, suggesting a bias toward negative stimuli as a mechanism related to the maintenance and development of depression in this group. Similarly, Zalla, Fernandez, Pieron, Seassau, and Leboyer (2016) showed reduced IOR in a group of autistic adults using faces with a distinct eye gaze direction as a cue which may relate to developmental deficits in their social functioning.

Apart from the question of the mechanisms underpinning the IOR effect, it seems that the question of its very essence and definition also remains open (see e.g., Hunt & Kingstone, 2003; Lupiáñez, Martín-Arévalo, & Chica, 2013; Michalczyk & Bielas, 2019). This variety of assumptions regarding IOR may portend that what has been given the label "IOR" is actually more than one phenomenon (Dukewich & Klein, 2015). This term may thus function as a common denominator for various processes which appear to follow similar pattern but with different, potentially even inverse, dynamics, e.g., a time course. It would also mean that IOR may be a phenomenon with a layered structure and can be analyzed on different levels or from different perspectives requiring more than one theoretical explanation. This is why it can be used to study the frames of reference on which various psychological processes can act (Lupiáñez et al., 2006).

The description of orienting to exogenously presented stimuli in the Posner paradigm (Posner & Cohen, 1984), within which IOR was discovered, seems to reflect similar concepts described previously within a physiological framework by Ivan Pavlov (1927). Drawing on the Pavlovian conceptualization of reflexes, and Sokolov's (1963) conceptual theory of orienting response (OR) which followed, the IOR effect can also be reconceptualized and formulated in these terms as the habituation, i.e., the gradual reduction, of OR with the repeated presentations of a stimulus that is not paired with an outcome (Dukewich, 2009). According to Pavlov (1951-52), there are individual differences in the dynamics of the reflexes of animals and humans which depend on the properties of the central nervous system. Among these properties, Pavlov regarded strength of excitation, and its counterpoint of protective inhibition, as the primary forces responsible for the fundamental characteristics of CNS. Pavlov's theory of CNS properties and his research on their regulatory function governing any behavior have inspired modern psychologists, e.g., Gray (1964, 1981), Eysenck (1957, 1967), Zuckerman (1979, 1994), Tellegen (1985), to devise their own theories of temperament/personality. Also, Strelau (1983, 1998) is the author of the Regulative Theory of Temperament (RTT), which is one of the prominent arousal-oriented theories of this aspect of personality, and the questionnaire to measure the behavioral expressions of psychophysiological constructs embedded in the Pavlovian tradition (Strelau, 1972). According to his account, temperament "refers to basic, relatively stable personality traits expressed mainly in the formal (energetic and temporal) characteristics of behavior" (Strelau, 1998, p. 165). Psychometric studies have resulted in the identification of six such traits which represent individual differences in energetic and temporal aspects of behaviors, and relate to each other in a kind of self-regulatory structure which can be assessed with the Formal Characteristics of Behavior–Temperament Inventory (FCB-TI): briskness, perseveration, sensory sensitivity, (emotional) reactivity, endurance, activity (see Strelau & Zawadzki, 1993). Among them, reactivity (ER) is thought to be a basic dimension of temperament which is at the root of other temperamental traits. It explicitly relates to the Pavlovian category of the strength of excitation (Strelau, 1983) while detailing it. According to Strelau, reactivity determines the general intensity, i.e., the power, of response and is assumed to function as a principal moderator of the stimulating and temporal value of behaviors. Besides other interactions among the traits, ER is inversely related to endurance (EN) and activity (AC). Activity refers to undertaking behaviors with different stimulative value. By modulating the frequency and intensity of interactions with our environment, one can maintain the optimal individual level of arousal. Endurance is understood in terms of the ability to sustain demanding reactions despite fatigue, competing stimuli (distractors) or emotional stressors. Thus, the higher that individuals are in terms of ER, the less enduring and persistent they are expected to be in the processing of given stimuli and prone to engage in the processing of novel ones. For instance, those with high ER who have engaged in a demanding attentional activity are likely to react in a somewhat stronger manner to given stimuli and disengage faster than less reactive individuals. Strelau (1983) points out that the efforts to find neurophysiological substrate of temperamental conditions have been in vain. However, viewing nervous activity as depending on some kind of limited energy resource (e.g., see Gailliot et al., 2007), one can assume a neuroendocrine mechanism which could be responsible for this interaction. It would involve the amount of the energy mobilized and, subsequently, consumed for a reaction. The more energy mobilized, the more intensively it is used up, which results in the reaction's depletion, burning out, and ceasing. It would therefore naturally have an impact on the ability to seek out novel stimulation.

The interaction between two fundamental dimensions and conditions of behavior according to modern temperament (personality) theories, namely approach to and engagement in versus inhibition of stimulation, seems to be reflected in the essence of the phenomenon of IOR. Approaching inhibition of return in this perspective may lead to the main question of whether individual differences in temperament express themselves in the parameters, i.e., the time course and magnitude of the effect. A positive answer to this question would mean that an individual's temperament might even affect microscale behavioral processes and effects, e.g., those evinced in saccadic movements, measured in milliseconds. We do not know of any other studies of individual differences in the time course and magnitude of IOR that use saccadic responses to measure its effect on behavior.

In this psychophysiological context, our main aim is to investigate the relationship between the dynamics of IOR and temperament. In order to do so, we decided to draw on Strelau's Regulative Theory of Temperament, as embedded in the Pavlovian tradition. This is due to its potential to explain a subject's general tendencies to engage and disengage from activity in their reciprocal relationships. Particularly, we choose to focus on the temperamental trait of reactivity as a crucial factor of individual differences in regulatory processes. In this regard, we follow one of the key points of RTT, according to which reactivity as a temperamental (personality) trait is in a reverse relation with endurance and activity, in turn leading to the question of whether reactivity has a differential effect on the time course and the magnitude of inhibition of return as an attentional process. More concretely, supposing that high reactivity derives from more energy being mobilized in response to a given stimulus, which is followed by subsequently more intensive response depletion, we assume that in a cueing task the highly reactive individuals do not orient and dwell on the cued location as long as the lower reactive subjects. This may result in the earlier onset of IOR, i.e., at shorter SOAs, in the former group. Moreover, as reactivity is also thought to be in a reverse relation with activity, it can further be assumed that highly reactive individuals' resources for a new orienting response and then the ability to reorient to an uncued location also attenuates more intensively. Therefore, one can also assume that the interplay between disengagement and the novelty seeking drive in order to reengage is more balanced in such cases. This may result in the magnitude of IOR being smaller in the subjects who are high in reactivity than in those who are lower in ER. Thus, putting all those presumptions together, we came up with the following main hypothesis: IOR appears earlier in subjects who are high in reactivity and its magnitude is smaller than in those who are low in ER.

2. Method

2.1. Participants

Ninety university students (63 females, 27 males; aged 19 to 24) participated in the present study. The participants were residents of the Krakow metropolitan area (Poland). They were recruited from the candidates who had performed the Formal Characteristics of Behavior–Temperament Inventory (FCB-TI). The final sample of participants was selected from a larger pool of candidates (approximately 300) on the basis of their standardized scores on the scale of Emotional Reactivity to make up three groups of: 30 low, 30 medium and 30 high reactive individuals. They were then invited to take part in the study. The participants were unaware of the purpose of the experiment. They received a monetary reward for their participation (in the amount of 25 €). All had normal or corrected-to-normal vision. The research was carried out in accordance with the Code of Ethics of the World Medical Association (The Declaration of Helsinki). Individuals gave informed consent before their participation in the study.

2.2. Formal Characteristics of Behavior–Temperament Inventory

Formal Characteristics of Behavior–Temperament Inventory is a self-report questionnaire which consists of 120 yes-no statements grouped into six scales referring to the temperamental traits characterized in the Regulative Theory of Temperament: briskness, perseveration, sensory sensitivity, (emotional) reactivity, endurance, activity. There are 20 items pertaining to each trait. 1 point for an answer indicates a higher level and 0 points for an answer indicates a lower level of a particular trait. The sums can therefore range from 0 to 20 for each temperament trait (Strelau & Zawadzki, 1993).

2.3. Apparatus and stimulus

Participants were seated 75 cm away from a 24 inch LCD monitor (Asus, 120 Hz refresh rate) with their heads stabilized in a chin and forehead rest. Eye movements were recorded monocularly by an EyeLink1000 plus (SR Research, Ltd., Canada) system sampling at 1000 Hz. Before each session the system was calibrated with the eyelink three-point calibration. Each calibration was checked by means of a three-point validation procedure. All stimuli were presented on a black background. At the beginning of each trial, an automatic drift correction procedure was applied by presenting a red dot (0.2° in diameter) in the center of the screen. If a subject failed to fixate for at least 500 ms within a 1.5° boundary region surrounding the dot after it had appeared, then a manual drift correction was performed. Following successful drift correction, a gray dot (0,2°) was displayed in the center of the screen which served as a fixation point during each trial. Two open gray squares (2° × 2°, edge thickness: 0.1°) having the function of placeholders were displayed 5° to the left and to the right from fixation. The cue was a white frame (0.4°) administered by the thickening of all of the edges of a placeholder. The target was a green square (1.9°) presented centrally within a placeholder.

2.4. Procedure

A fixation point and two placeholders at each side of it were displayed for 1000 ms. Then, a cue appeared for 100 ms, randomly to the left or right of the fixation. As previous studies have demonstrated, IOR is a robust effect that starts at a SOA of approximately 300 ms and might last as long as 3 s or even longer (Danziger, Kingstone, & Snyder, 1998; Tassinari, Biscaldi, Marzi, & Berlucchi, 1989). It therefore seems beneficial that, in research on individual differences in the time course of IOR, a wide range of SOAs should be taken into consideration. That is why we decided to examine the inhibitory effect in our study at SOAs of: 150, 250, 1500 and 2500 ms. Following this various time interval after the onset of the cue, the target was presented, and the subjects were instructed to react to it by executing a saccade as quickly as possible to the target. The target was displayed on the screen until the answer was recorded (or disappeared after 1000 ms). The saccadic reaction time (SRT) was defined as the latency of the saccade that landed within a 2° boundary region surrounding the target. According to the algorithm for saccade detection, an eye movement was determined as a saccade when a fixed velocity threshold of 30°/s and an acceleration threshold of 8000°/s2 were exceeded. If a subject broke fixation or responded before the onset of the target or a successful saccade response was not made within 1000 ms after the target onset, the trial was coded as an error and placed in the pool of unfinished trials to be completed later. The session consisted of seven blocks of 32 trials each (a total of 224 trials). The first block was defined as training and removed from further analysis. In each block there were 16 (50%) valid trials in which targets were presented at cued locations, and 16 (50%) invalid trials in which the targets were displayed at locations opposite the cue (Fig. 1).

2.5. Data analysis

The statistical package Statistica 13.1 (TIBCO Software Inc., 2017) was used for data analysis; however, effect sizes were calculated using ESCI software (Cumming, 2016) and post hoc power analysis were estimated with use of G*Power 3.1.9.3 (Faul, Erdfelder, Lang, & Buchner, 2007).

The data were first submitted to a descriptive analysis. 0.56% of responses were rejected as anticipatory (saccades latency shorter than 100 ms). The results were then subjected to the outlying procedure (>3SD), but no more trials were classified as needing to be removed. Mean SRTs were calculated for the remaining correct SRTs. Subsequently, all participants' mean SRTs were analyzed with a 3 × 2 × 4 ANOVA with Emotional Reactivity (low-ER, medium-ER, high-ER) as between-subjects variable and Validity (valid, invalid) and SOA (150, 250, 1500 and 2500 ms) as a within-subjects variable. The validity effects were calculated as the difference between reaction times in valid trials (a target appears in the same location as a cue) and invalid trials (a target appears in the opposite location to a cue). The positive value of this difference reflects the facilitation effect, while a negative value implies the IOR effect.

3. Results

The ANOVA showed a statistical significance for all three main effects. There was a main effect of SOA, with saccades being faster in a longer cue-target times interval compared with shorter ones ($F(3,261) = 32.43$; $p < 0.001$; $\eta_p^2 = 0.27$). There was also reliable validity effect: latencies of the saccade were longer in the previously cued location (valid trials), compared to uncued locations (invalid trials) ($F(1,87) = 19.79$; $p < 0.001$; $\eta_p^2 = 0.18$). The main effect of ER was also significant ($F(2,87) = 3.90$; $p < 0.05$; $\eta_p^2 = 0.08$): saccade latencies of the

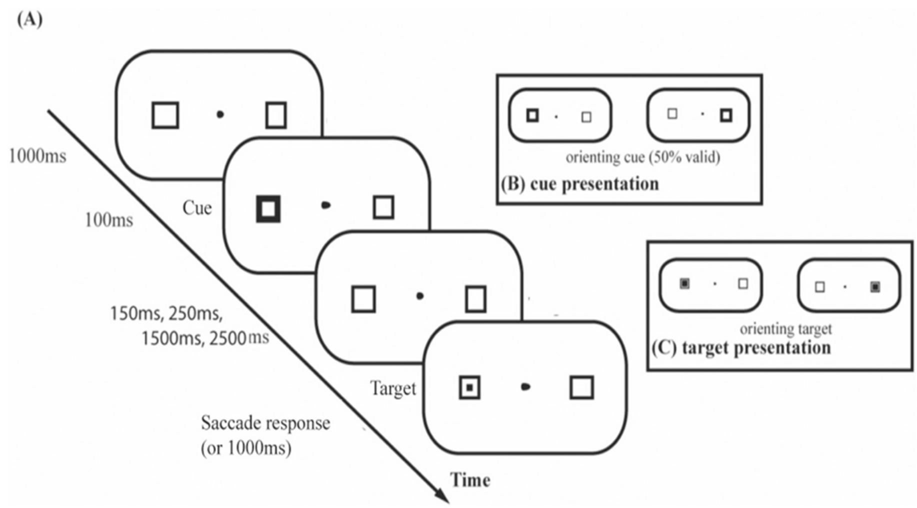

Fig. 1. Sequence of events in a cueing task for each group.

participants in a medium-ER groups were longer (M = 345, SD = 7.5) than those participants in the low-ER (M = 322, SD = 7.6) and high-ER groups (M = 318, SD = 7.6). The interaction between validity and ER (F (2,87) = 1.14; $p = 0.32$) and between SOA and ER (F(6,261) = 0.53; $p = 0.78$) were not significant. However, SOA interacted significantly with validity (F(3,261) = 33.76; $p < 0.001$; $\eta_p^2 = 0.28$): at shorter SOA of 150 ms was achieved reliable facilitation effect (i.e. saccade latencies were faster in valid than invalid trials), while at longer SOAs of 1500 ms and 2000 ms a decent IOR effect (i.e., saccade latencies were faster in invalid than valid trials) was observed. There was also a significant three-way interaction of validity, SOA and ER (F(6,261) = 2.51; $p < 0.05$; $\eta_p^2 = 0.05$). Detailed information about differences between valid and invalid trials in different SOAs and different ER groups are shown in Table 1.

Planned comparisons (1-tailed *t*-test) confirmed that the facilitation effect (i.e. a positive value of differences between SRT in valid and invalid trials) was obtained at a short SOA of 150 ms in all three groups of ER: low-ER (t(29) = 2.39; $p < 0.05$; Mdiff = 21; SDdiff = 8.2; d = 0.37; power = 0.63), medium-ER (t(29) = 3.70; $p < 0.001$; Mdiff = 30; SDdiff = 8.25; d = 0.56; power = 0.91) and high-ER (t(29) = 2.63; p < 0.05; Mdiff = 20; SDdiff = 8.2; d = 0.45; power = 0.77). The difference between facilitation effect in low-ER and medium-ER subjects was not significant (t(58) = 0.66; $p = 0.5$). Similarly, the differences between IORs in the low-ER and high-ER and between IORs in the medium-ER and the high-ER groups were also not significant (t(58) = 0.19; $p = 0.85$ and t(58) = 0.94; $p = 0.34$, respectively).

At a 250 ms SOA, the reversed effect of IOR (i.e. a negative value of differences between SRT in valid and invalid trials) was observed, but only in high-ER (t(29) = −2.13; $p < 0.05$; Mdiff = −13; SDdiff = 8.5; d = 0.30; power = 0.48), while in low-ER and medium-ER groups, the differences between valid and invalid trials was not significant (t(29) = −1.03; p = 0.3; Mdiff = −9; SDdiff = 8.48 and t(29) = 0.56; $p = 0.57$; Mdiff = 6; SDdiff = 8.5, respectively).

At the longer SOA of 1500 ms, planned comparisons (1-tailed *t*-test) revealed a significant IOR effect in all three groups: low-ER (t(29) = −5.05; $p < 0.001$; Mdiff = −35; SDdiff = 7.63; d = 0.75; power = 0.99), medium-ER (t(29) = −4.54; $p < 0.05$; Mdiff = −44; SDdiff = 7.61; d = 0.76; power = 0.99) and high-ER (t(29) = −2.28; p < 0.05; Mdiff = −14; SDdiff = 7.60; d = 0.35; power = 0.59). Similarly, at SOA of 2500 ms IOR effect was also obtained in all three groups of ER: low-ER (t(29) = −5.47; p < 0.001; Mdiff = −35; SDdiff = 6.98; d = 0.73; power = 0.98), medium-ER (t(29) = −5.05; p < 0.001; Mdiff = −4; SDdiff = 6.97; d = 0.73; power = 0.98) and high-ER (t(29) = −2.49; $p < 0.05$; Mdiff = −16; SDdiff = 6.98; d = 0.40; power = 0.69) (Fig. 2).

The difference between the magnitude of IORs in low-ER and medium-ER subjects was not significant as it was neither in the SOA of 1500 ms (t(58) = 0.75; $p = 0.45$) nor the SOA of 2500 ms (t(58) = 0.64; $p = 0.52$). However, in both SOAs (1500 ms and 2500 ms) the IOR effect was significantly larger in the group of medium-ER than in high-ER subjects (t(58) = 2.63; $p < 0.01$; Mdiff = 29; d = 0.68; power = 0.83 and t(58) = 2.43; $p < 0.05$; Mdiff = 25; d = 0.62; power = 0.76, respectively for each of the SOAs). Also, in the group of low-ER subjects, the magnitude of of IOR was significantly larger than in the high-ER group in both SOAs: 1500 ms (t(58) = 2.30; p < 0.05; Mdiff = 20; d = 0.60; power = 0.74) and 2500 ms (t(58) = 2.06; p < 0.05; Mdiff = 18;

Table 1
Mean SRTs and standard errors for valid and invalid trials at different SOAs and in ER groups.

SOA	Low ER (***N*** = 30)		Medium ER (N = 30)		High ER (N = 30)	
	Valid	Invalid	Valid	Invalid	Valid	Invalid
150	292 ± 8.4	313 ± 10.6	315 ± 8.4	345 ± 10.6	295 ± 8.4	315 ± 10.6
250	345 ± 9.2	336 ± 10.3	356 ± 9.2	362 ± 10.3	336 ± 9.2	323 ± 10.3
1500	343 ± 8.8	308 ± 8.8	373 ± 8.8	329 ± 8.8	330 ± 8.8	316 ± 8.8
2500	335 ± 9.2	300 ± 8.2	362 ± 9.2	321 ± 8.2	322 ± 9.2	306 ± 8.2

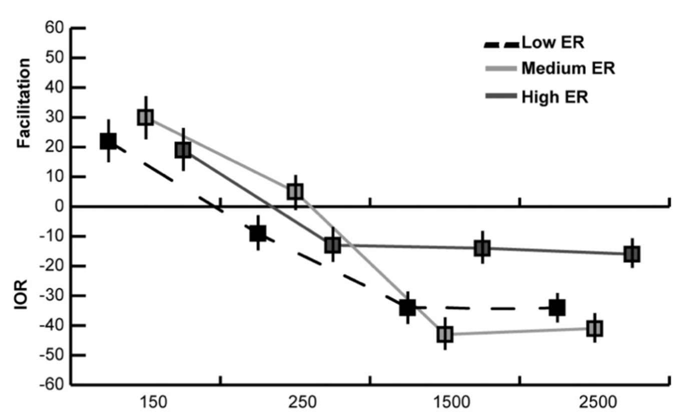

Fig. 2. Validity effects as a function of different SOAs in different groups (low, medium and high ER). The validity effect was calculated as the difference between SRTs in valid and invalid trials. The positive value of this difference reflects the facilitation effect and negative values indicate the IOR effect. Error bars show standard deviation.

d = 0.53; power = 0.64).

4. Discussion

The aim of the present study was to consider IOR as a phenomenon encapsulating the interaction between two fundamental dimensions of behavior understood in terms of temperamental traits: either engaging in or withdrawing from activity. In this manner, we came up with the leading question of whether the dynamics, i.e., the time course and magnitude of IOR, reflect individual differences in temperament. Following the tenets of the Regulative Theory of Temperament (Strelau, 1983, 1998), we arrived at the main overarching hypothesis: in subjects who are high in reactivity, IOR appears earlier and its magnitude is smaller than in those who are low in ER.

The results of our study appear to confirm these combined assumptions. In the individuals with high ER scores, the IOR effect is already present at the SOA of 250 ms while in those with lower ER rates, the difference between reaction times in valid and invalid trials is not yet significant at this time. In highly reactive subjects, therefore, IOR tends to develop faster than in those lower on ER. Furthermore, it continues to be present at longer SOAs as it is in the latter group. Moreover, as it has also been assumed, the effect of IOR in highly reactive subjects is indeed smaller than in those with lower ER. At the SOAs of 1500 and 2500 ms, reaction times of high-ER individuals are significantly longer in valid than invalid trials. However, the magnitude of IOR is significantly larger in the group of low and medium-ER than in high-ER subjects at these SOAs.

We chose to situate the main aim of our study within the Pavlovian framework because the process of orienting to exogenously presented stimuli in the Posner paradigm (Posner & Cohen, 1984) resembles essentially what has been already described in physiological terms by Pavlov (1927) as the orienting reflex of an organism directing its receptor organs toward novel and potentially salient events in the environment. Furthermore, we decided to analyze IOR in terms of RTT, that is embedded in the Pavlovian tradition, because the temperamental traits which it specifies might even be seen as reflected in the very essence of this effect. RTT, besides distinguishing the particular temperamental traits, addresses them as intertwined components which make up a self-regulatory structure. Such basic temperamental traits have been identified following the Pavlovian approach, which stemmed from his concept of the strength of excitation versus its counterpart of protective inhibition as the primary properties of the central nervous system and the forces governing its activity. That is why the theory seems well suited in terms of the IOR effect, which also consists of interrelated processes of facilitation and inhibition. We believe that this conceptual framework not only provides the basis to explain the results of this study but also to look at IOR as an effect which reflects basic temperamental traits: engaging in versus withdrawal from, and inhibition of activity. If so, IOR could even be called a temperamental effect. Within this framework, we began by focusing on emotional reactivity which is presumed to be inversely related to endurance and activity as temperamental traits to be revealed in the essence of IOR.

The results of the study confirm this description in the manner that in highly reactive subjects, attentional activity tends to attenuate faster which results in earlier IOR than in less reactive individuals. Furthermore, as the activity of high-ER individuals is also expected to decrease more dynamically elsewhere, the magnitude of the effect should be smaller in this group, a fact also confirmed by the results. It should, however, be noticed that, according to this rationale, IOR should also tend to disappear faster at longer SOAs as compared to less reactive individuals. We assume that this might be the case but at SOAs longer than 2500 ms, something we did not take into consideration in this study and which certainly counts as one of its limitations.

In the paper, we also referred to Klein's proposal to link IOR with executive control and his suggestion that a delayed appearance of IOR, or no IOR, in some cases might result either from some form of executive deficits (Klein, 2004, 2005) or from the overload of executive control processes (Klein, Castel, & Pratt, 2006). Apparently, our results differ from those which Klein (2004) pointed to in regard to the time course of IOR. However, we are inclined to think that even in this regard they are not contradictory but rather complementary, both on a theoretical and empirical level. This would not only be because we focused on a group of healthy young adults but also because of possible diverse dynamics of IOR depending on the particular aspect of overall psychological functioning it refers to. Since the discovery of IOR, the question of the mechanisms underpinning this effect remains open, as does the question of its very essence and definition. Researchers seem to have quite different understandings of what IOR actually is. Such variety may portend that the term IOR refers to more than one phenomenon, requiring more than one theoretical explanation (Dukewich & Klein, 2015). This umbrella term may therefore function as a common denominator for various processes which appear to follow a similar pattern but with different dynamics depending on the level analyzed or the perspective employed. That is why it may present, as we believe, different characteristics depending on conceptual and experimental circumstances in which it is investigated to be considered part of the IOR puzzle. It should also be mentioned here that we only controlled demographic data to a limited extent in our study and thus the existence of other factors (e.g. economic, marital, or employment status) influencing the characteristics of IOR to some extent may not be excluded.

According to Strelau and Zawadzki (1993), the concept of emotional reactivity as a temperamental trait refers basically to negative emotions, mainly anxiety. Individuals who are high in ER are prone to react impulsively and less effectively in stressful circumstances. This raises the following questions: 1) of the relation between the results of this study and the results of other research on individual differences in the dynamics of IOR in such cases of emotion regulation disorders as: phobias, depression, autism spectrum disorder or substance abuse, and 2) of their value as a transdiagnostic marker. Although the research results on individual differences in IOR across clinical psychology seem far from being conclusive, the effect is often found in such cases to be reduced (e.g., Colzato & Hommel, 2009; Dai & Feng, 2009; Zalla et al., 2016), not present or strong but independent of diagnostic group as compared to the control individuals (Berdica et al., 2014). The results of our study seem to follow a similar pattern with the magnitude of IOR being smaller in highly reactive individuals which can be explained by decreased cognitive control to recover from attentional capture and to return attention to an initial state. However, the effect also starts earlier than in those who are low in ER which would even seem to conflict with this explanation. That is why we rather chose to explain the results in light of RTT without referring to higher executive functions. Within this framework, high reactive individuals would disengage faster (earlier IOR) but would also have fewer energy resources to engage elsewhere (smaller IOR). We are inclined to follow this rationale also because the temperamental trait of reactivity itself, regardless of its magnitude, should not rather be understood in psychopathological terms and the Formal Characteristics of Behavior–Temperament Inventory is not a tool to measure clinical conditions in the strict sense. It is rather a certain configuration of temperamental traits within the framework of RTT which may be considered as dysfunctional (Strelau & Zawadzki, 1993). We have not included these other traits in this study and this is perhaps a limitation to be mentioned here.

It is worth noticing that there are also some non-linear patterns in the results which need to be mentioned here given the linear character of FCB-TI to quantify temperament. In our study, the magnitude of IOR at longer SOAs was significantly smaller in the high-ER group than in medium-ER and low-ER subjects. However, it was not the greatest in low-ER subjects, as one might infer by opposition, but in the medium-ER group. In order to provide a heuristic explanation of these results, one might point to the notion of optimal arousal level (Duffy, 1962; Hebb, 1949) and to the magnitude of IOR as indicating its effectiveness as a foraging facilitator (Klein, 2004). At least since the research of Yerkes and Dodson (1908), it has been believed that moderate arousal is generally the best for performance. The quality of cognitive processes will not only likely suffer when arousal is very high, but also when it is low. The largest magnitude of IOR as a mechanism to enhance cognitive performance would thus reflect the optimal level of arousal in medium reactive subjects.

Within the framework of RTT, the effective regulation of arousal is thought to be achieved in an interplay of the component traits of which an individual's temperament consists. In this paper, due its exploratory character, we began by focusing on emotional reactivity, because, according to RTT, it plays a key role in the whole structure of temperament. It is, for example, expected to be inversely related to endurance and activity. If so, one may expect that the pattern of IOR in the case of activity should also be inversely related to the results obtained in this study for reactivity. RTT includes, however, more temperamental traits and sheds light also on their reciprocal relations. Therefore, we are inclined to believe that RTT can further serve in order to analyze IOR and help to develop its formula in temperamental terms due to its potential to also show other temperamental traits which would allow us to see them in their reciprocal interactions. For example, particularly promising in regard to the question of the temperamental conditions of IOR seems to be briskness as an ability to react quickly, to maintain a high tempo in performing activities, and to shift easily in response to changes in the surroundings from one reaction to another or perseveration as a tendency to continue and repeat behavior after the cessation of a stimuli evoking this behavior in the first place. The question of whether and how these traits are reflected in the dynamics of IOR remains open and, in our opinion, deserves further investigation.

Nevertheless, the results of the present study already suggest that temperament has a differential effect on IOR. This means that individual's temperament can even influence microscale behavioral processes and effects measured in milliseconds. Concretely, due to the method employed in this study, one may conclude that temperamental (personality) traits reveal themselves in saccadic movements or, in brief, that a personality is revealed by someone's eyes.

5. Conclusion

Temperamental differences were discovered in the time course and magnitude of IOR. In individuals who are high in terms of reactivity, IOR starts earlier but its magnitude is smaller in comparison with those lower in reactivity. The results of the study suggest that temperament/personality can influence microscale psychological processes and effects such as those evinced in saccadic movements.

Acknowledgments

The research was supported by the National Science Centre, Poland [grant 2019/03/X/HS6/01944] www.ncn.gov.pl given to Jacek Bielas. The funders had no role in the study design, data collection and analysis, decision to publish, or preparation of the manuscript.

References

Avila, C. (1995). Facilitation and inhibition of visual orienting as a function of personality. *Personality and Individual Differences, 18*, 503–509.

Berdica, E., Gerdes, A., Pittig, A., & Alpers, G. W. (2014). Inhibition of return in fear of spiders: Discrepant eye movement and reaction time data. *Journal of Ophthalmology*. https://doi.org/10.1155/2014/183924

Colzato, L. S., & Hommel, B. (2009). Recreational use of cocaine eliminates inhibition of return. *Neuropsychology, 23*(1), 125.

Cumming, G. (2016). Exploratory software for confidence intervals. https://thenewstatistics.com/itns/esci/ Accessed: 2021-07-07.

Dai, Q., & Feng, Z. (2009). Deficient inhibition of return for emotional faces in depression. *Progress in Neuro-Psychopharmacology and Biological Psychiatry, 33*(6), 921–932.

Danziger, S., Kingstone, A., & Snyder, J. J. (1998). Inhibition of return to successively stimulated locations in a sequential visual search paradigm. *Journal of Experimental Psychology. Human Perception and Performance, 24*, 1467–1475. https://doi.org/10.1037/0096-1523.24.5.1467

Duffy, E. (1962). *Activation and behavior*. New York: Wiley.

Dukewich, K. R. (2009). Reconceptualizing inhibition of return as habituation of the orienting response. *Psychonomic Bulletin & Review, 16*(2), 238–251. https://doi.org/10.3758/PBR.16.2.238

Dukewich, K. R., & Klein, R. M. (2015). Inhibition of return: A phenomenon in search of a definition and a theoretical framework. *Attention Perception & Psychophysics, 77*(5), 1647–1658. https://doi.org/10.3758/s13414-015-0835-3

Eysenck, H. J. (1957). *The dynamics of anxiety and hysteria*. London: Routledge & Kegan Paul.

Eysenck, H. J. (1967). *The biological basis of personality*. Springfield, IL: Thomas.

Faul, F., Erdfelder, E., Lang, A.-G., & Buchner, A. (2007). G*Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behavior Research Methods, 39*, 175–191.

Fuentes, L. J., Vivas, A. B., & Humphreys, G. W. (1999). Inhibitory tagging of stimulus properties in inhibition of return: Effects on semantic priming and flanker interference. *Quarterly Journal of Experimental Psychology Section A: Human Experimental Psychology, 52*, 149–164. https://doi.org/10.1080/027249899391269

Gailliot, M. T., Baumeister, R. F., DeWall, C. N., Maner, J. K., Plant, E. A., Tice, D. M., Brewer, L. E., & Schmeichel, B. J. (2007). Self-control relies on glucose as a limited energy source: Willpower is more than a metaphor. *Journal of Personality and Social Psychology, 92*(2), 325–336.

Gray, J. A. (1964). *Pavlov's typology: Recent theoretical and experimental developments from the laboratory of B. M. Teplov*. Oxford: Pergamon Press.

Gray, J. A. (1981). A critique of Eysenck's theory of personality. In H. J. Eysenck (Ed.), *A model for personality* (pp. 246–276). Berlin: Springer-Verlag.

Hebb, D. O. (1949). *Organization of behavior*. New York: Wiley.

Hunt, A. R., & Kingstone, A. (2003b). Inhibition of return: Dissociating attentional and oculomotor components. *Journal of Experimental Psychology. Human Perception and Performance, 29*(5), 1068–1074. https://doi.org/10.1037/0096-1523.29.5.1068

Itti, L., & Koch, C. (2001). Computational modelling of visual attention. *Nature Reviews Neuroscience, 2*(3), 194–203.

Klein, R. M. (1988). Inhibitory tagging system facilitates visual search. *Nature, 334*, 430–431. https://doi.org/10.1038/334430a0

Klein, R. M. (2000). Inhibition of return. *Trends in Cognitive Sciences, 4*(4), 138–147.

Klein, R. M. (2004). Orienting and inhibition of return. In M. S. Gazzaniga (Ed.), *The cognitive neurosciences* (3rd ed., pp. 545–559). Cambridge, MA: MIT Press, Bradford Books.

Klein, R. M. (2005). On the role of endogenous orienting in the inhibitory aftermath of exogenous orienting. In U. Mayr, E. Awh, & S. Keele (Eds.), *Developing individuality in the human brain: A tribute to Michael I. Posner* (pp. 45–64). Washington, DC: APA Books.

Klein, R. M., Castel, A. D., & Pratt, J. (2006). The effects of memory load on the time course of inhibition of return. *Psychonomic Bulletin & Review, 13*(2), 294–299.

Klein, R. M., & MacInnes, W. J. (1999). Inhibition of return is a foraging facilitator in visual search. *Psychological Science, 10*(4), 346–352.

Lupiáñez, J., Klein, R. M., & Bartolomeo, P. (2006). Inhibition of return: Twenty years after. *Cognitive Neuropsychology, 23*, 1003–1014. https://doi.org/10.1080/02643290600588095

Lupiáñez, J., Martín-Arévalo, E., & Chica, A. B. (2013). Is inhibition of return due to attentional disengagement or to a detection cost? The detection cost theory of IOR. *Psicológica, 34*, 221–252.

Michalczyk, Ł., & Bielas, J. (2019). The gap effect reduces both manual and saccadic inhibition of return (IOR). *Experimental Brain Research, 237*, 1643–1653.

Mishra, R. K., Hilchey, M. D., Singh, N., & Klein, R. M. (2012). On the timecourse of exogenous cuing effects in bilinguals: Higher proficiency in a second language is associated with more rapid endogenous disengagement. *Quarterly Journal of Experimental Psychology, 65*(8), 1502–1510.

Morriss, J., & McSorley, E. (2019). Intolerance of uncertainty is associated with reduced attentional inhibition in the absence of direct threat. *Behaviour Research and Therapy, 118*, 1–6.

Myles, O., Grafton, B., & MacLeod, C. (2020). Anxiety & inhibition: Dissociating the involvement of state and trait anxiety in inhibitory control deficits observed on the anti-saccade task. *Cognition and Emotion, 34*(8), 1746–1752.

Pavlov, I. P. (1927). In G. V. Anrep (Ed.), *Conditioned reflexes*. London: Oxford University Press. Trans.

Pavlov, I. P. (1951-1952). *Complete works* (2nd ed.). SSSR Academy of Sciences, Moscow and Leningrad (in Russian).

Posner, M. I., & Cohen, Y. (1984). Components of visual orienting. In H. Bouma, & D. Bouwhuis (Eds.), *Attention and performance X* (pp. 531–556). London: Lawrence Erlbaum Associates Ltd.

Posner, M. I., Rafal, R. D., Choate, L. S., & Vaughan, J. (1985). Inhibition of return: Neural basis and function. *Cognitive Neuropsychology, 2*, 211–228.

Rothbart, M. K., & Derryberry, D. (1981). Development of individual differences in temperament. In M. E. Lamb, & A. L. Brown (Eds.), *Advances in developmental psychology* (Vol. 1, pp. 37–86). Hillsdale, NJ: Erlbaum.

Rothbart, M. K., & Posner, M. (1985). Temperament and the development of selfregulation. In L. C. Hartlage, & C. F. Telzrow (Eds.), *The neuropsychology of individual differences: A developmental perspective* (pp. 93–123). New York: Plenum.

Sokolov, E. N. (1963). *Perception and the conditioned reflex*. In S. W. Waydenfeld, R. W. Trans., & A. D. B. Clarke (Eds.). New York: Pergamon.

Strelau, J. (1972). A diagnosis of temperament by nonexperimental techniques. *Polish Psychological Bulletin, 3*, 97–105.

Strelau, J. (1983). *Temperament, personality, activity*. London: Academic Press.

Strelau, J. (1998). *Temperament: A psychological perspective*. New York: Plenum Press.

Strelau, J., & Zawadzki, B. (1993). The formal charactersistics of behavior – Temperament inventory (FCB-TI): Theoretical assumptions and scale construction. *European Journal of Personality, 7*, 313–336. https://doi.org/10.1002/per.2410070504

Tassinari, G., Aglioti, S., Chelazzi, L., Marzi, C. A., & Berlucchi, G. (1987). Distribution in the visual field of the costs of voluntarily allocated attention and of the inhibitory after-effects of covert orienting. *Neuropsychologia, 25*, 55–71. https://doi.org/10.1016/0028-3932(87)90043-1

Tassinari, G., Biscaldi, M., Marzi, C. A., & Berlucchi, G. (1989). Ipsilateral inhibition and contralateral facilitation of simple reaction time to non-foveal visual targets from non-informative visual cues. *Acta Psychologica, 70*, 267–291. https://doi.org/10.1016/0001-6918(89)90026-7

Tellegen, A. (1985). Structure of mood and personality and their relevance to assessing anxiety with an emphasis on self-report. In A. H. Tuma, & J. D. Master (Eds.), *Anxiety and anxiety disorders* (pp. 681–706). Hillsdale, NJ: Erlbaum.

TIBCO Software Inc.. (2017). Statistica (data analysis software system), version 13.1. http://statistica.io.

Wilson, K. E., Lowe, M. X., Ruppel, J., Pratt, J., & Ferber, S. (2016). *Attention, Perception, & Psychophysics, 78*, 209–217.

Yerkes, R. M., & Dodson, J. D. (1908). The relation of strength of stimulus to rapidity of habit formation. *Journal of Comparative Neurology & Psychology, 18*, 459–482.

Zalla, T., Fernandez, L. G., Pieron, M., Seassau, M., & Leboyer, M. (2016). Reduced saccadic inhibition of return to moving eyes in autism spectrum disorders. *Vision Research, 127*, 115–121.

Zuckerman, M. (1979). *Sensation seeking: Beyond the optimal level of arousal*. Hillsdale, NJ: Erlbaum.

Zuckerman, M. (1994). *Behavioral expressions and biosocial bases of sensation seeking*. New York: Cambridge University Press.