Personality and Individual Differences 63 (2014) 10–15

Contents lists available at ScienceDirect

Personality and Individual Differences

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

# Psychological refractory period in introverts and extraverts

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ARTICLE INFO

*Article history:*
Received 8 October 2013
Received in revised form 7 January 2014
Accepted 11 January 2014
Available online 12 February 2014

*Keywords:*
Extraversion
Reaction time
Psychological refractory period
Lateralized readiness potentials
Speed of information processing

ABSTRACT

The present study was designed to explore extraversion-related differences in the psychological refractory period (PRP). PRP refers to a bottleneck of information processing that becomes evident when participants are required to respond to two signals (S1 and S2) presented in rapid succession. If this capacity limit of premotor information processing is essential for differences in speed of information processing between introverts and extraverts, magnitude of the PRP effect should vary as a function of extraversion. Due to the failure of previous attempts to establish extraversion-related differences in the PRP effect, we also obtained lateralized readiness potentials (LRPs). For this purpose, 63 introverted and 63 extraverted female participants were tested with a standard PRP design. Extraverts responded faster to S2 and exhibited shorter stimulus-locked LRP latencies compared to introverts. Although a general PRP effect could be shown at the behavioral and psychophysiological level, there was no indication for any extraversion-related differences in PRP. Thus, extraversion-related differences in speed of information processing at the premotor level appear unlikely to originate from individual differences in the capacity limits underlying the PRP phenomenon. Furthermore, our findings provide converging evidence for the notion that extraversion-related individual differences in processing speed depend on specific task demands.



## 1. Introduction

Numerous empirical findings and theoretical accounts of extraversion as a basic dimension of personality suggest individual differences in sensorimotor information processing between introverts and extraverts (for reviews see Bullock & Gilliland, 1993; Rammsayer, 1998). These effects may be attributable to faster initiation of movement or faster motor execution in extraverts compared to introverts (e.g., Doucet & Stelmack, 1997; Wickett & Vernon, 2000). Considerably fewer studies endorse the view of extraversion-related differences at the premotor stage of information processing including processes such as stimulus analysis, stimulus evaluation, and response selection (Houlihan & Stelmack, 2011; Stahl & Rammsayer, 2004). The present study was designed to further elucidate extraversion-related differences in the transmission of sensory input into motor output with special attention paid to premotor processes. For this purpose, we employed an experimental paradigm providing an opportunity to assess extraversion-related individual differences in speed of information processing at a specified *premotor* bottleneck of information processing referred to as the *psychological refractory period* (PRP).

Individual differences in sensorimotor information processing have been assumed to be most salient at processing stages characterized by capacity limits (cf., Cooper & Regan, 1982). As highlighted by recent cognitive research (e.g., Marois & Ivanoff, 2005), a major capacity limit of premotor information processing is represented by PRP. This bottleneck of information processing becomes evident when participants are required to respond to two signals (S1 and S2) presented in rapid succession. The response to S2 is increasingly delayed with decreasing stimulus onset asynchrony (SOA) between S1 and S2. Psychophysiological studies on the PRP effect employing event-related potential techniques have established the temporal boundary of the PRP bottleneck to a stage between stimulus consolidation in working memory and motor preparation (Jentzsch, Leuthold, & Ulrich, 2007; Osman & Moore, 1993; Sommer, Leuthold, & Schubert, 2001).

To the best of our knowledge, there are only two studies on extraversion-related differences in PRP. In his pioneering study, Brebner (1998) proceeded from his motor theory of extraversion (Brebner, 1985). In general terms, this theory predicts more elaborate analysis of stimulus information for introverts compared to extraverts and faster motor response preparation for extraverts than for introverts. Based on this conceptual framework, Brebner

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http://dx.doi.org/10.1016/j.paid.2014.01.033
0191-8869/

(1998) hypothesized that, in a PRP task, extraverts should respond faster than introverts to both S1 and S2. While his prediction of faster responses to S1 for extraverts was not born out by his data, extraverts, indeed, showed less delayed responses to S2 than did introverts. He also established a general PRP effect, as indicated by slower response times to S2 with decreasing SOA between S1 and S2. It remained unclear, however, whether the magnitude of this effect differed reliably between introverts and extraverts. In a subsequent study, also applying a PRP paradigm, Indermühle, Troche, and Rammsayer (2011) failed to reveal extraversion-related individual differences in PRP.

A major reason why differences between introverts and extraverts may not become evident in response time measures can be deduced from Brebner's motor theory of extraversion. According to this account, introverts' lower speed of response organization could be compensated by their more efficient stimulus analysis. Thus, response time measures may fail to disclose differences between introverts and extraverts in speed of information processing due to a lack of functional sensitivity (Rammsayer & Stahl, 2004).

As a psychophysiological approach that facilitates direct assessment of extraversion-related individual differences in speed of premotor stimulus processing and aspects of motor processing, (Rammsayer & Stahl, 2004; Stahl & Rammsayer, 2004) proposed the lateralized readiness potential (LRP). The LRP appears several hundred milliseconds before voluntary hand movement and is larger contralateral to the hand to be moved. In choice-response tasks, responses initiated by the right and left hand elicit greater electrical activity at scalp sites contralateral to the activated hand (Gratton, Coles, Sirevaag, Eriksen, & Donchin, 1988). Thus, LRP reflects the asymmetrical cortical activation of hand-specific lateralization processes. The interval between the onset of stimulus presentation and the onset of the LRP, referred to as stimulus-locked LRP (S-LRP) latency, represents a measure of the time required for premotor information processing, including stimulus analysis, stimulus evaluation, and response selection. In contrast, the interval between the onset of the LRP and completion of the motor response is referred to as the response-locked LRP (LRP-R) latency and, thus, reflects the time course of processes involved in central response organization and execution of the motor response.

The available LRP data on extraversion-related individual differences in sensorimotor information processing provided a rather consistent overall pattern of results (Houlihan & Stelmack, 2011; Rammsayer & Stahl, 2004; Stahl & Rammsayer, 2004, 2008). While introverts appear more efficient than extraverts in the processing of stimulus signals to respond, as indicated by introverts' shorter S-LRP latency, extraverts' shorter LRP-R latency is indicative of their faster response organization and execution. To date, however, no LRP data on extraversion-related individual differences have been obtained for experimental tasks based on the PRP paradigm. Therefore, it remains unclear whether these results also hold for the typical PRP situation where participants are required to respond to two signals presented in rapid succession.

In the present study, special attention was paid to the functional significance of the processing limitation associated with the PRP. If this major capacity limit of premotor information processing is essential for differences in information processing between introverts and extraverts, the PRP effect should be effectively modulated by the individual level of extraversion.

## 2. Method

### 2.1. Participants

A total of 190 female undergraduate students were screened for individual levels of extraversion. They filled in the extraversion scale of the German adaptation of the Eysenck Personality Questionnaire-Revised (Ruch, 1999). This sample was divided into three groups according to the extraversion score. The lower and upper third were enrolled in the present study. Thus, the final sample consisted of 126 participants ranging in age from 18 to 31 years. The 63 participants with extraversion scores less than 10 were considered as introverts and the 63 participants with extraversion scores greater than 15 were considered as extraverts. This resulted in mean (±SD) extraversion scores of 5.3 ± 2.2 and 19.1 ± 1.6 for introverts and extraverts, respectively.

Because gender differences have been reported for extraversion scores (Lynn & Martin, 1997) and evoked potentials (Gurrera, Salisbury, O'Donnell, Nestor, & McCarley, 2005), only female participants were tested. Participants were nonsmokers and reported normal hearing and normal or corrected-to-normal vision. They were asked to refrain from drinking coffee or other caffeinated beverages for at least three hours before the experiment. For taking part in this study, participants were paid the equivalent of USD 30.00.

### 2.2. PRP Task

A modified version of the standard PRP design (e.g., Jentzsch et al., 2007; Osman & Moore, 1993) was employed using an auditory (S1) and a visual (S2) two-choice task.

#### 2.2.1. Apparatus and Stimuli

Auditory stimuli (S1) were 1000- and 1075-Hz sine-wave tones presented for 60 ms through headphones with an intensity of 88 dB. Visual stimuli (S2) were the letters *X* and *O* presented in white on a black background for 200 ms in the centre of a monitor screen. Letters subtended a visual angle of 0.5°. Responses were recorded by a Cedrus® response pad operated by the index and middle fingers of the left and right hand.

#### 2.2.2. Procedure

An experimental session comprised 11 blocks; one practice block followed by 10 experimental blocks. Each block consisted of 64 trials. Each trial began with the presentation of a fixation cross followed after 500 ms by one of the tones (S1). After a randomly chosen SOA of either 100, 200, 400, or 800 ms, one of the letters (S2) was presented. Each of the S1 and S2 stimuli was presented in half of the trials within a block in randomized order.

Participants were instructed to respond as rapidly as possible to each of the two stimuli but to avoid making errors. The two-choice response to the tones and to the letters had to be performed with the index and middle fingers of both hands. High and low tones were mapped to the left and right middle fingers, respectively; the letters *X* and *O* were assigned to left and right index finger responses. The participant's response was followed by a blank interval with a duration randomly chosen between 1000 and 1250 ms before the next trial began.

As an index of performance, response times to S1 and S2 were recorded. All trials with incorrect responses to S1 or S2 as well as trials with response times less than 150 ms or longer than 2000 ms were excluded from data analysis.

### 2.3. Electrophysiological recordings

The LRP was recorded with Ag/AgCl electrodes at electrode sites C3′ and C4′ positioned 1 cm anterior to C3 and C4, respectively. These positions were chosen because of their correspondence to the hand areas of the precentral motor cortex (cf., Coles, 1989). Horizontal and vertical movements in the electrooculogram were recorded from electrode positions supra- and infraorbitally to the right eye, and 2 cm external to the outer canthus of each eye.