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The point of no return in motor response: Extraversion-related differences

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Abstract

The present study aimed at investigating extraversion-related individual differences in response organization. For this purpose, 50 female participants completed the Eysenck Personality Questionnaire and Dickman's Impulsivity Inventory and performed a stop-signal reaction-time task. The most significant finding was that the so-called point of no return, defined as the point in time where a once initiated response can no longer be withheld, was reliably earlier reached with increasing individual extraversion scores. Extraverts' earlier point of no return appears to be a function of their tendency to continue and augment current response activity as implied by Brebner's theory of extraversion. Additional commonality analysis revealed that the point of no return is primarily modulated by the personality dimension of extraversion rather than the more specific trait of dysfunctional impulsivity.

Key words: Extraversion, response organization, stop-signal task, stop-signal delay

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According to Brebner's (1980, 1985) theory of extraversion hypothetical central processing systems can be in one of two states, excitation or inhibition. Either of these states can be induced by the demands for stimulus analysis or response organization as a function of extraversion. While introverts are assumed to produce excitation from stimulus analysis and, therefore, persist more in perceptual activities, extraverts are predicted to produce excitation from process associated with response organization. In line with this theory, extraverts should make faster motor responses than introverts. This prediction appears to be consistent with the outcome of several studies that measured reaction time (RT) independently of movement time (MT) (e.g., Doucet & Stelmack, 1997; Rammsayer, 1995; Wickett & Vernon, 2000). In these studies, RT represents the time required from stimulus onset to the release of a home button whereas MT is the time required from the release of the home button to the subsequent press of a target button. While RT is an index of central processing speed, MT appears to be largely independent of cognitive task requirements and can be considered a valid indicator of response execution (Doucet & Stelmack, 1997, 2000).

At first glance, faster MT in extraverts compared to introverts seems to confirm Brebner's notion that extraverts should make faster motor responses than introverts do. According to Brebner's model, however, both stimulus analysis and response organization refer to central processes that precede the emission of a motor response. Therefore, extraversion-related differences should manifest themselves also in the latency of central processes associated with RT, such as motor programming and motor preparation. Recent electrophysiological studies (Rammsayer & Stahl, 2004; Stahl & Rammsayer, 2006) using the lateralized readiness potential (LRP)[3] to investigate extraversion-related differences in speed of sensorimotor processing, provided evidence for faster central response organization in extraverts compared to introverts.

The main aim of the present study was to provide additional converging evidence for Brebner's theory of extraversion by applying another experimental paradigm that can be assumed to efficiently evoke high levels of motor excitation, referred to as the stop-signal paradigm (e.g., Osman, Kornblum, & Meyer, 1986). With this paradigm, participants are engaged in a choice-reaction time task, and occasionally and unpredictably, they are presented with a stop signal that tells them to inhibit their response. This paradigm has been utilized to investigate so-called *horse race models* (e.g. Band, van der Molen, & Logan, 2001; Stahl & Gibbons, 2007). Horse race models describe a "race" between two independent, concurrent processing systems, one system controlling the overt motor response (*go system*) and another one to stop the ongoing response (*stop system*). On both, go trials and stop trials, the go system is activated by a go signal. On stop trials, however, the additionally presented stop signal activates the inhibiting stop system. These concurrent signals are presented with an experimentally varied temporal delay. As could be shown, response probability increases with increasing signal delay, i.e., the later the stop signal was presented, the harder the response could be withheld. If the participant was able to successfully inhibit the overt motor response, the stop system was "winner" of the race, whereas, if the participants responded in spite of a stop signal, the go system was superior.

[3] The LRP indicates *hand specific activation* recorded over the primary motor cortex (for details, see Coles, 1989). The interval from stimulus onset to LRP onset indicates the duration of stimulus analysis and the time from LRP onset to response onset is used as an index for the duration of response organisation.

It has been suggested that a point in time exists where the participant will no longer be able to withhold his or her response (McGarry & Franks, 1997; Osman et al., 1986). This point in time is referred to as *point of no return* (Bartlett, 1958). Beyond this point of no return, ballistic rather than controlled processes are assumed to be prevailing. Ballistic processes are ones that immediately precede, and are inextricably linked to, overt motor responses. Once having launched, ballistic processes must proceed to completion and, upon completion, trigger the onset of overt movement. Osman et al. (1986) established a countermanding procedure based on an adaptive algorithm to estimate a participant's individual point of no return. According to this adaptive procedure, the stop-signal delay was increased or decreased from trial to trial depending on the participant's response on the immediately preceding trial. If the participant failed to stop his or her response on the preceding trial, the stop-signal delay was decreased, whereas successful inhibition of a response was followed by an increase of the stop-signal delay. This tracking procedure also allows a reliable estimation of the non-observable latency of inhibitory processes referred to as stop-signal reaction time (SSRT). Thus, SSRT represents an index of inhibitory control obtained by subtracting stop-signal delay from mean go-signal reaction time (Logan, Schachar, & Tannock, 1997).

Proceeding from Brebner's theory of extraversion, the following major predictions can be derived: Due to higher task-induced levels of motor excitation, an increasing level of extraversion should result in faster responses and more wrong-hand responses on go trials. For the same reason, on stop trials, more extraverted participants should fail to withhold their response as long as more introverted participants. Hence, the stop-signal delay should decrease with increasing extraversion scores. Eventually, less pronounced inhibitory control as reflected by longer SSRT could be expected for extraverts compared to introverts. These predictions have been tested in the present study. Since there is some evidence that SSRT may be influenced by individual impulsiveness scores (Logan et al., 1997; but see also Rodríguez-Fornells, Lorenzo-Seva, & Andrés-Pueyo, 2002), additional measures of functional and dysfunctional impulsivity were also obtained.

Method

Participants

Participants were 50 female undergraduate psychology students ranging in age from 19 to 43 years (mean and standard deviation of age: 23.5 ± 5.9 years). They received course credit for their participation in the study and were naive about the experimental hypotheses. All participants had normal hearing and normal or corrected-to-normal vision.

Personality Questionnaires

Participants filled in the German adaptation of the Eysenck Personality Questionnaire-Revised (EPQ-R; Eysenck & Eysenck, 1991) by Ruch (1999). This 102-item questionnaire contains four scales: Extraversion (E: 23 items), Neuroticism (N: 25 items), Psychoticism (P: 32 items), Lie or Social Desirability (L: 22 items). For additional assessment of individual impulsiveness the German adaptation of Dickman's Impulsivity Inventory (DII; Dickman,

1990) was applied. The DII consists of two scales assessing functional (11 items) and dysfunctional aspects of impulsivity (12 items). Functional impulsivity represents a trait that results in rapid inaccurate performance in situations where such a style is optimal. Dysfunctional impulsivity, on the other hand, refers to the tendency to engage in rapid, error-prone information processing due to an inability to use a slower, less error-prone strategy.

Stop-Signal Task

As visual response signals, the uppercase letters *G*, *T*, *U*, and *V* were used. Each letter was presented for 1,000 ms in the center of the computer screen subtending a visual angle of about .60 degrees in height. A chin rest was used to maintain a constant posture and distance of 65 cm to the computer screen. The auditory stop signal consisted of a 1,000-ms sine-wave tone presented through headphones at an intensity of 59 dB.

The participants were instructed to respond with one hand to letters *G* and *V* and with the other hand to letters *T* and *U*. The assignment of letter pairs to hand was held constant within each participant but balanced across participants. An experimental session lasted approximately 60 min. Each session started with three practice blocks. While the first two practice blocks consisted of 44 go-trials, the third practice block as well as each of the subsequent 14 experimental blocks consisted of 28 go and 16 stop trials. Within each block, each letter was presented the same number of times. Between blocks, there was a short break of approximately 30 s.

At the beginning of each trial, a white fixation cross was presented for 500 ms followed by the visual response signal, which was presented after a variable foreperiod. Participants were instructed to respond as quickly as possible by pressing one of the two designated response keys, but to inhibit their response when the stop signal was presented. The next trial started 1,500 ms after the offset of the visual response signal. Instructions stressed speed on go trials over successful inhibition on stop trials. The delay between the onset of the visual response signal and the auditory stop signal was adjusted individually by an adaptive staircase method (Levitt, 1971) converging on the individual stop-signal delay that enabled the participant to successfully inhibit her response in 50% of all stop trials. The initial value of the stop-signal delay was defined as a participant's mean RT obtained in the second practice block minus 100 ms. If the participant successfully inhibited her response, for the next stop trial, the delay was reduced by 20 ms, but increased by 20 ms, if she failed to inhibit her response.

As measures of performance, RT, stop-signal delay, SSRT, and wrong-hand responses on go trials were determined. RT was computed for correct go trials. A participant’s individual stop-signal delay was determined by averaging the stop-signal delays across all stop trials. This measure indicates the critical delay at which a participant was able to inhibit her response with a probability of 0.5. SSRT was calculated by subtracting the mean stop-signal delay from mean RT as suggested by Logan et al. (1997).

Result

Means, standard deviations, and Pearson correlations among personality measures are presented in Table 1. Significant positive correlations were found between the extraversion scale and the psychoticism (*r* = .28, *p* < .05) and dysfunctional impulsivity scales (*r* = .34, *p* < .05). Furthermore, scores on dysfunctional impulsivity were positively associated with neuroticism (*r* = .45, *p* < .001). Functional impulsivity was negatively correlated with psychoticism (*r* = -.49, *p* < .001). No other significant correlations could be observed.

Table 2 shows means and standard deviations of all behavioral measures obtained. Almost no response errors could be observed as indicated by an extremely low percentage of wrong-hand responses of 0.29%. Intercorrelations among all performance measures are depicted above the means. RT was positively associated with stop-signal delay reflecting that participants with slower responses usually had longer stop-signal delays (*r* = .78, *p* < .001). Percentage of wrong hand responses was negatively related to stop-signal delay (*r* = -.44, *p* < .001) but positively to SSRT (*r* = .40, *p* < .01). This indicates that, on go trials, number of response errors increased with shorter stop-signal delays and longer SSRTs. While SSRT and RT did not show a reliable correlation coefficient (*r* = .08, *p* > .1), there was a negative correlational relationship between SSRT and stop-signal delay (*r* = -.53, *p* < .001). These latter findings may suggest that SSRT, which was calculated as the difference between mean RT and mean stop-signal delay, appears to be a function of stop-signal delay rather than general response speed as reflected by RT.

Correlations between personality scores and all performance measures obtained in the stop-signal task are presented in Table 3. A statistically significant negative correlational relationship could be observed between extraversion scores and both mean RT (*r* = -.35, *p* < .05) and stop-signal delay (*r* = -.38, *p* < .01). This finding indicates faster responses as well as an earlier point of no return in response preparation with an increasing individual level of extraversion. Higher scores on dysfunctional impulsivity were also associated with shorter RT (*r* = -.29, *p* < .05), while the negative correlation between stop-signal delay and dysfunctional impulsivity just failed to reach the 5% level of statistical significance (*r* = -.28, *p* < .052).

Table 1:
Intercorrelations, mean, standard deviation (SD), maximum, and minimum of all personality scales applied.

	Extraversion (E)	Psychoticism (P)	Neuroticism (N)	Dysfunctional Impulsivity (DImp)	Functional Impulsivity (FImp)
E					
P	.28*				
N	-.07	.20			
L	-.04	-.18	.02		
DImp	.34*	-.02	-.45***		
FImp	.27	.49***	.15	.10	
Mean	14.8	8.4	13.0	5.3	4.2
SD	4.9	4.2	5.3	3.4	3.3
Minimum	4	1	5	0	0
Maximum	22	20	24	11	12

* p < .05; *** p < .001 (two-tailed)

Table 2:
Intercorrelations, mean, standard deviation (SD), maximum, and minimum of all behavioral measures.

	Reaction Time (RT)	Percentage of Wrong-Hand Responses P(W)	Stop-Signal Delay (SSD)	Stop-Signal Reaction Time (SSRT)
RT				
P(W)	.25			
SSD	.78***	.44**		
SSRT	.08	-.40**	-.53**	
Mean	545	99.5	333	217
SD	85.6	3.9	92.9	55.6
Minimum	375	98.5	128	157
Maximum	766	99.9	526	446

** p < .01 ; *** p < .001 (two-tailed)

Table 3:
Correlations between personality scores and all behavioral measures obtained.

	Extraversion	Psychoticism	Neuroticism	Dysfunctional Impulsivity	Functional Impulsivity
Reaction Time	-.35*	.01	.16	-.29*	-.05
Percentage of Wrong-Hand Responses	-.05	.10	-.12	-.02	.13
Signal Delay	-.38**	.07	.23	-.28	.00
Stop-Signal Reaction Time	.09	-.10	-.12	.08	-.10

* p < .05; ** p < .01 (two-tailed)

In a second step, we tried to further elucidate the functional relationship between extraversion and dysfunctional impulsivity, on the one hand, and RT and stop-signal delay on the other. As standard correlational analysis does not allow determining the unique and the confounded contribution of several predictor variables to the explanation of the variance of the criterion variable, additional commonality analyses (Cooley & Lohnes, 1976) were performed. In multivariate prediction of a single criterion measure by two predictors, commonality analysis partitions the criterion variance into the unique contribution of each predictor and the confounded contribution of both predictors combined, referred to as commonality. With regard to the prediction of RT, commonality analysis revealed that the confounded contribution of both extraversion and dysfunctional impulsivity was 5.6% of explained variance in RT. The unique contribution of extraversion to the prediction of RT was 7.3%, whereas dysfunctional impulsivity contributed 3.0% of unique variance. When applying commonality analysis to the prediction of the stop-signal delay, criterion variance was partitioned into 5.7% of commonality, 10.4% of unique variance provided by extraversion, and 2.2% of unique variance contributed by dysfunctional impulsivity.

Discussion

Based on Brebner’s (1980, 1985) theory of extraversion, the present study aimed at investigating extraversion-related individual differences in sensorimotor processing. Applying a stop-signal task, four hypotheses were tested to provide converging experimental evidence for Brebner's notion that higher levels of extraversion should be associated with an enhanced level of task-induced motor-excitation. This functional relationship between extraversion and level of motor excitation has been predicted to result in faster RT and more wrong-hand responses on go trials with increasing extraversion individual scores. The observed negative correlation between extraversion and RT was consistent with our prediction. However, there was no indication of more wrong-hand responses with increasing levels extraversion in the present study. The low error rate of .0029 for wrong-hand responses indicates that the task demands produced by the letter-discrimination task applied in the present study were rather low. Thus, the lack of a correlational relationship between number of wrong-hand responses and individual level of extraversion might be due to task demands too low to evoke considerable extraversion-related individual difference in responses errors.

Based on tasks like the present stop-signal task, several authors (e.g., Bartlett, 1958; McGarry & Franks, 1997; Osman et al., 1986) put forward the assumption of a so-called “point of no return” within the time course of sensorimotor information processing. The point of no return is defined as the point in time where a once initiated response can no longer be withheld. The location of this point can be indirectly inferred from signal delay; the shorter the signal delay the earlier the assumed point-of no-return has been reached. According to Brebner's theory, motor excitation in extraverts should manifest itself behaviourally in the tendency to continue and augment current response activity. Therefore, on stop trials, more extraverted participants should sooner fail to withhold their response as compared to more introverted participants. This led us to the prediction that the stop-signal delay should decrease with increasing extraversion scores, i.e., the point of no return should be reached earlier with increasing extraversion scores. This prediction is clearly supported by the reliable negative correlation of signal delay and extraversion score obtained in the present study.

There are at least two possible reasons that may account for an earlier point of no return in extraverts compared to introverts. First, speed of stimulus analysis may be faster in extraverts than in introverts. As a consequence, response organization should be initiated sooner and, thus, the point of no return is reached earlier in extraverts. Alternatively, proceeding from the assumption of no extraversion-related individual differences in speed of stimulus analysis, processes associated with central motor excitation may be faster in extraverts than in introverts. From this perspective, extraverts' earlier point of no return could be considered a function of a more rapid central response organization as implied by Brebner's theory of extraversion.

Most recently, electrophysiological studies utilizing LRPs for assessing extraversion-related differences in speed of sensorimotor processing revealed faster speed of stimulus analysis in introverts compared to extraverts on visual choice-RT tasks which were highly similar to the letter discrimination task applied in the present experiment (Stahl & Rammsayer, 2004, 2007). On the other hand, extraverts showed reliably faster motor processing on go/no-go tasks as indicated by the time course of processes involved in central response organization and execution of the motor response (Rammsayer & Stahl, 2004; Stahl & Rammsayer, 2006). Within the framework of these electrophysiological findings, the earlier point of no return observed with increasing extraversion scores reflects extraverts' higher level of motor excitation rather than faster stimulus analysis. Previous findings by Doucet and Stelmack (1997, 2000) of faster MT in extraverts compared to introverts – especially within the acceleration phase of movement execution – additionally supported this consideration.

Our final hypothesis referred to the relationship between individual extraversion scores and level of inhibitory control as reflected by internal RT to the stop signal (SSRT). SSRT has been assumed to reflect the speed of inhibitory processing and, thus, may represent a chronometric indicator of the extent of inhibitory control (Logan et al., 1997). Proceeding from Brebner's assumption of increased motor excitation in extraverts than introverts, we hypothesized less pronounced inhibitory control, as reflected by longer SSRT, with increasing extraversion scores. Such a relationship, however, was not born out by our data. This finding is consistent with the outcome of a previous study (Avila & Parcet, 2001) that also failed to establish a correlational relationship between extraversion and SSRT. Hence, individual differences in internal reaction time to the stop signal do not appear to contribute to the explanation of extraversion-related differences in sensorimotor processing.

Recently, the stop-signal task was employed to study differences in response inhibition between high- and low-impulsive individuals (e.g., Avila & Parcet, 2001; Logan et al., 1997; Marsh, Dougherty, Mathias, Moeller, & Hicks, 2002; Rodríguez-Fornells et al., 2002; Stahl & Gibbons, 2006). To dissociate impulsiveness- from extraversion-related aspects of sensorimotor processing, we additionally measured functional and dysfunctional impulsiveness (Dickman, 1990). It seems noteworthy that the pattern of results for *dysfunctional* impulsivity was quite similar to the one for extraversion (negative correlation with RT and signal delay, respectively). Since extraversion and dysfunctional impulsivity were shown to be positively correlated, commonality analyses were performed to determine the unique contribution of extraversion and dysfunctional impulsivity, respectively, as two predictors of individual variability in RT and stop-signal delay. Commonality analyses revealed that extraversion provided a substantially larger portion of unique variance than dysfunctional impulsivity in the prediction of RT and stop-signal delay. Thus, both aspects of sensorimotor processing, response speed and the point of no return, appear to be primarily modulated by the personality dimension of extraversion rather than the more specific trait of dysfunctional impulsivity.

Neurophysiological studies showed that, among others, substantia nigra and striatum, which both are part of major dopaminergic systems, are involved in response inhibition as required in a stop trial (for review, see Brunia, 2004). Furthermore, there is converging evidence for a functional relationship between extraversion and the dopamine systems in the brain, that is, the dopamine responsiveness is higher in introverts than in extraverts (for review, see Rammsayer, 2004). The extraversion-related differences in dopaminergic modulation might be responsible for the above-mentioned performance differences in a stop task.

To summarize, in the present stop-signal task extraverts showed faster responses and shorter stop-signal delays compared to introverts. This latter finding indicates that the point-of-on return is earlier reached in extraverts compared to introverts. Extraversion-related individual differences in the location of the point of no return provide converging evidence for the functional significance of response organization as a major process underlying behavioural differences between introverts and extraverts as suggested by Brebner's theory of extraversion.

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