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Putting the temporal resolution power (TRP) hypothesis to a critical test: Is the TRP-*g* relationship still more fundamental than an optimized relationship between speed of information processing and *g*?

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ABSTRACT

The present study investigated whether the relationship between temporal resolution power (TRP) and general intelligence (*g*) is more fundamental than the relationship between speed of information processing (SIP) and *g* when a) TRP and SIP are assessed with an equally effective test battery, and b) when the relationship between SIP and *g* is strengthened by an increase of task demands. A heterogeneous sample of 110 male and 118 female participants completed a short version of the Berlin Intelligence Structure test as a measure of *g*. TRP was assessed with three psychophysical timing tasks and SIP with three different reaction time tasks in which cognitive task demands were systematically increased across task conditions. SIP variance was divided into a component representing speed of processing increasing cognitive task demands and a component representing processing speed independent of the experimental manipulation. The relationship between TRP and *g* was robust and unaffected by both SIP components. SIP caused by the enhanced cognitive task demands explained variance in *g* irrespective of TRP, whereas TRP completely accounted for the relationship between speed unaffected by the experimental manipulation and *g*. In contrast to previous findings, however, the effect of TRP on the SIP-*g* relationship ceases when SIP is derived from cognitively more demanding reaction time tasks.

1. Introduction

The mental speed approach to human intelligence provides a large body of evidence for a positive relationship between speed of information processing (SIP) and psychometric intelligence (Deary, 2000; Doebler & Scheffler, 2015; Jensen, 1998, 2006; Sheppard & Vernon, 2008). More intelligent individuals accomplish cognitive processes faster than less intelligent individuals (Vernon, 1987). One of the most frequently used experimental tasks is the Hick reaction time task (Hick, 1952; for a review see Proctor & Schneider, 2017), in which the number of response alternatives is systematically increased across task conditions. In the initial condition, the simple reaction time condition, an individual is supposed to respond as fast as possible to an imperative stimulus presented in a single stimulus location. In the subsequent choice reaction time conditions, the number of possible stimulus locations and, thus, the number of response alternatives, is systematically increased. Studies on individual differences in SIP revealed that Hick reaction times were negatively associated with psychometric intelligence and that this association became stronger with increasing numbers of response alternatives (Jensen, 1987; Neubauer, Riemann, Mayer, & Angleitner, 1997; Rammsayer, Pahud, & Troche, 2017; Rammsayer & Troche, 2016).

Proceeding from the assumption that the processing of time-related information is critical for the relationship between speed and intelligence, Rammsayer and Brandler (2002, 2007) introduced the temporal resolution power (TRP) hypothesis. Critical for the TRP hypothesis were two findings. First, individual differences in timing accuracy and temporal sensitivity as assessed with different psychophysical timing tasks (e.g., duration discrimination tasks or temporal-order judgment tasks) could be assigned to a single factor by means of exploratory and confirmatory factor analyses (Rammsayer & Brandler, 2004; Rammsayer & Troche, 2014; Stauffer, Haldemann, Troche, & Rammsayer, 2012). Second, scores on this factor, representing task-independent TRP of the brain, consistently showed a moderate to strong positive association with psychometric intelligence (Haldemann, Stauffer, Troche, & Rammsayer, 2011, 2012; Helmbold & Rammsayer, 2006; Rammsayer & Brandler, 2007; Troche & Rammsayer, 2009a). Based on these findings, the TRP hypothesis posits that individuals with higher TRP process information faster and coordinate mental operations better than those with lower TRP (e.g., Rammsayer & Brandler,

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2002, 2007; Troche & Rammsayer, 2009a). Both, the faster processing of information and the better coordination of mental operations led to less strained processing systems and, eventually, to more efficient information processing resulting in higher scores on tests assessing psychometric intelligence.

The assumption that higher TRP of the brain leads to better-coordinated information processing was supported by Troche and Rammsayer (2009b), who reported a strong correlation not only between TRP and psychometric intelligence, but also between TRP and working memory capacity. Furthermore, the study by Rammsayer and Brandler (2007) combined a large battery of psychophysical timing tasks and the Hick paradigm to investigate the functional interplay of TRP, SIP, and the general factor of psychometric intelligence (*g*). In this study, TRP accounted for a larger portion of variance in *g* than SIP, suggesting that TRP is a more proximate predictor of *g*. However, TRP and SIP also shared common variance that predicted a substantial portion of variance in *g*. Based on this finding, Helmbold, Troche, and Rammsayer (2007) performed a follow-up study, in which the predictive power of TRP and SIP as well as potential mediating effects with regard to the prediction of *g* were examined. When specified as related predictors, TRP and SIP correlated substantially, but only TRP significantly predicted *g*. Accordingly, a subsequent mediation analysis revealed that the relationship between SIP and *g* was completely mediated by TRP suggesting that TRP is indeed the more proximate predictor of *g* that also accounts for the well-established relationship between SIP and *g*.

However, the superiority of TRP in prediction of *g* as well as the mediational effect might be explained by the unbalanced assessment of SIP and TRP in the study by Helmbold et al. (2007). While TRP was assessed as a composite measure based on seven psychophysical timing tasks, SIP was measured by a single Hick reaction time task with three task conditions. As a result, the TRP factor was much broader than the SIP factor that solely comprised variance specific to the Hick task. Thus, the SIP factor's restricted level of generality could have hampered its predictive strength for *g*.

The primary aim of the present study was to put the interplay between TRP, SIP, and *g* to a more valid and more critical test than the previous study by Helmbold et al. (2007). For this reason, TRP and SIP were assessed with an equivalent battery of three tasks. For TRP, we used the same three psychophysical timing tasks as used by Troche and Rammsayer (2009b), which showed to be valid indicators of TRP (e.g., Rammsayer & Brandler, 2004). For SIP, the objective was to obtain a generalized composite measure alike TRP, which has an equal chance to be an effective predictor of *g*. Therefore, we needed a more comprehensive battery of SIP tasks and complemented the Hick paradigm with two additional SIP tasks. Furthermore, previous research showed that the relation between SIP and *g* is stronger for more demanding task conditions that yield prolonged reaction times (Coyle, 2017; Jensen, 1998, 2006; Stankov, 2000; Vernon & Weese, 1993). Hence, analogous to the Hick paradigm, the newly added SIP tasks should offer the possibility to systematically increase the cognitive task demands across three task conditions. Based on this idea, for both new tasks, the least demanding conditions were simple reaction time task conditions comparable to the least demanding task condition of the Hick paradigm. The increase of task demands, however, should functionally differ between the tasks. Proceeding from the basic principles of the flanker task (Eriksen & Eriksen, 1974) and the Continuous Performance Test (CPT; Rosvold, Mirsky, Sarason, Bransome, & Beck, 1956), two more demanding task conditions were implemented for each of the two tasks. By doing so, we aimed at increasing demands on sustained attention (CPT) and on selective-focused attention (flanker task). Thus, the main goal of the present study was to investigate whether the relation between TRP and *g* is still more fundamental than the relation between SIP and *g* when, first, SIP and TRP are assessed with equivalently large test batteries of three tasks each and, second, SIP is measured by different cognitive demands in the SIP tasks. Both provisions are important preconditions to increase the likelihood for a possible functional relationship between SIP and *g* to become visible.

2. Method

2.1. Participants

The sample consisted of 150 participants taken from the study by Rammsayer et al. (2017) and 78 newly recruited participants. Participants were 110 male and 118 female volunteers ranging in age from 18 to 30 years (mean and standard deviation of age: 22.0 ± 2.9 years). One hundred thirty-six participants were university students and 104 participants had a non-academic background. All participants had normal or corrected-to-normal vision. For taking part in the present study, participants received either course credits or 45.00 Swiss francs. The study was approved by the local ethics committee and all participants gave their written informed consent.

2.2. Measurement of psychometric intelligence

Psychometric intelligence was assessed with a modified short version of the Berlin Intelligence Structure (BIS) test (Jäger, Süss, & Beauducel, 1997) including 18 subtests measuring processing capacity, processing speed, and memory as three major facets of psychometric intelligence. For each facet, two numerical, two figural, and two verbal subtests were used. For the statistical analyses, performance scores (i.e., the number of correctly solved items per subtest) were *z*-standardized for each individual. For latent modeling, a *g* factor of intelligence was derived from the aggregated mean z-scores of the three facets (cf. Stauffer, Troche, Schweizer, & Rammsayer, 2014). In a preceding pilot study, this *g* factor showed satisfactory test-retest reliability ($r_{tt} = 0.79$).

2.3. Assessment of speed of information processing

2.3.1. Hick reaction time task

A Hick reaction time task, originally introduced by Neubauer, Bauer, and Höller (1992), was applied. As in Helmbold et al.'s (2007) study, three levels of task demands were used. In the simple reaction time condition of the Hick task (H0), each trial started with the presentation of a rectangle (1.6 × 1.4 cm) in the center of the monitor screen. After a foreperiod varying randomly between 1000 and 2000 ms, a plus sign (0.5 × 0.5 cm) was presented in the center of the rectangle. Participants were instructed to respond as quickly as possible to the plus sign by pressing the designated response key. The next trial started 1100 ms after the response was given. The two-choice reaction time condition (H1) was identical to H0, except that two rectangles were presented arranged in a row and the plus sign was randomly presented in each of the two rectangles in 50% of the trials. The four-choice reaction time condition (H2) was identical to H1, except that four rectangles were presented in two rows and the plus sign was randomly presented in each of the four rectangles in 25% of the trials. Similar to the H0 condition, instructions for the H1 and H2 conditions emphasized to respond as quickly as possible to the imperative stimulus by pressing the response button corresponding to the rectangle with the imperative stimulus.

Each condition consisted of 32 experimental trials preceded by 10 practice trials. In case of a response error, a 1000 Hz feedback tone was presented for 200 ms. As a measure of performance, mean reaction time of correct responses was computed for each Hick condition.

2.3.2. Flanker task

The flanker task was adapted from the version used by Scheres et al. (2003). In the least demanding condition of the flanker task (F0), each trial started with the presentation of a fixation cross in the center of the monitor screen. After a foreperiod varying randomly between 600 and