



## Temporal and non-temporal sensory discrimination and their predictions of capacity- and speed-related aspects of psychometric intelligence

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### ABSTRACT

The temporal resolution power hypothesis explains individual differences in psychometric intelligence in terms of temporal acuity of the brain. This approach was supported by high correlations between temporal discrimination and psychometric intelligence. Psychometric intelligence, however, was frequently found to be related to non-temporal discrimination (e.g., frequency, intensity, brightness discrimination). The present study investigated 100 female and 100 male participants with the aim to elucidate the functional relations between psychometric intelligence and temporal and non-temporal discrimination ability. Supporting the assumption of dissociable mechanisms, non-temporal discrimination predicted directly capacity – but not speed-related aspects of psychometric intelligence whereas temporal discrimination predicted both aspects. A substantial correlation between temporal and non-temporal discrimination suggested that general discrimination ability might account for the relations of psychometric intelligence to temporal and non-temporal discrimination abilities. Findings point to an internal structure of general discrimination ability with some dimensions of discrimination more predictive to certain aspects of psychometric intelligence than others.

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### 1. Introduction

In his model of neuronal oscillations, Jensen (1982) proposed that individual differences in processing speed and psychometric intelligence can be attributed to differences in the rate of oscillation between refractory and excitatory states of neurons. The oscillation rate is supposed to determine speed and efficiency of transmission of neurally encoded information. In case that a stimulus is presented during the refractory state of a neuron, it is transmitted faster when the oscillation rate is high, i.e., when the neuron enters soon the excitatory phase of its cycle. Therefore, individuals with a high neuronal oscillation rate should process information more rapidly and, as a consequence, more efficiently. This faster and more efficient information processing should lead to better performance on psychometric tests of intelligence, particularly tests measuring speed- and capacity-related aspects of intelligence.

The temporal resolution power (TRP) hypothesis also refers to a hypothetical oscillatory process in the brain to account for the relationship between efficiency and speed of information processing as well as psychometric intelligence (Rammsayer & Brandler, 2002, 2007). According to this view, higher neural temporal resolution leads to faster information processing and to better coordination of mental operations resulting in better performance on intelli-

gence tests. Rammsayer and Brandler (2002) proposed that psychophysical timing tasks, assessing temporal sensitivity and timing accuracy, are the most direct behavioral measures of TRP. The TRP hypothesis has been supported by subsequent studies which found substantial correlations between psychometric intelligence and timing performance (Helmbold, Troche, & Rammsayer, 2006, 2007; Rammsayer & Brandler, 2007).

Most critical for the TRP hypothesis is the fact, that psychophysical timing tasks imply sensory discrimination. Sensory discrimination, however, is well-known to be related to psychometric intelligence not only for the temporal domain but also for other non-temporal sensory dimensions. For example, associations with psychometric intelligence were shown for color ( $r = .08$  to  $r = .32$ ; Acton & Schroeder, 2001), pitch ( $r = .42$  to  $r = .54$ ; Raz, Willerman, & Yama, 1987), or texture and shape in the tactile modality ( $r = .08$  to  $r = .29$ ; Stankov, Seizova-Cajić, & Roberts, 2001). Helmbold et al. (2006) showed that temporal discrimination explained a substantial portion of overall variability of psychometric intelligence independently of pitch discrimination. It was concluded, therefore, that the prediction of psychometric intelligence by temporal discrimination can be dissociated from the prediction by non-temporal discrimination performance. This conclusion, however, was limited because only one single pitch and one single temporal discrimination task were used in the study of Helmbold et al. (2006).

Another explanation for the association between intelligence and performance on discrimination tasks can be derived from the early investigations of Spearman (1904). He found that intelligence

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was almost perfectly related to a battery of discrimination tasks of different dimensions (e.g., pitch, weight and brightness) suggesting a functional relationship between unspecific, *general* discrimination ability (GDA) and intelligence. More recently, this finding was replicated by Deary, Bell, Bell, Campbell, and Fazal (2004) who reported a relation of  $r = .92$  between GDA and intelligence. From this perspective, the association between dimension-specific discrimination performance and psychometric intelligence can also be explained by the relation between GDA and psychometric intelligence. Proceeding from this assumption, GDA may also account for the observed relation between TRP and psychometric intelligence. Hence, the question arises whether the association between psychometric intelligence and temporal acuity reflects directly a time-specific neural property as suggested by the TRP hypothesis or whether it must be attributed primarily to the more general functional relationship between mental ability and GDA.

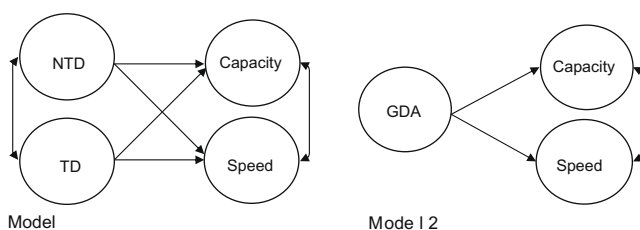
The aim of the present study was to compare two theoretical models (see Fig. 1). The first model expanded the investigation of Helmbold et al. (2006) to the level of latent variables by factorizing various non-temporal and temporal discrimination tasks. It is assumed that temporal and non-temporal discrimination abilities predict psychometric intelligence as two dissociable factors which, however, can be related to each other. The TRP hypothesis postulates that TRP affects both capacity- and speed-related aspects of psychometric intelligence (Helmbold & Rammsayer, 2006). Although theoretically unexplained, non-temporal discrimination was empirically found to be related to capacity- (Deary et al., 2004; Raz et al., 1987; Stankov et al., 2001) and speed-related aspects (Roberts, Stankov, Pallier, & Dolph, 1997). Therefore, the relations between temporal and non-temporal discrimination performances, on one hand, and capacity – as well as speed-related aspects of psychometric intelligence, on the other, were investigated concomitantly in the present study.

Model 2 proceeds from Spearman's (1904) assumption that a general discrimination ability predicts psychometric intelligence. In accordance with this view, temporal discrimination constitutes a factor indissociable from non-temporal discrimination. In other words, temporal and non-temporal discrimination tasks build a common factor referred to as GDA.

## 2. Method

### 2.1. Participants

Participants were 100 male and 100 female volunteers ranging in age from 18 to 30 years (mean  $\pm$  SD = 22.2  $\pm$  3.3 years). The sample comprised 93 university students, 89 vocational school students and apprentices, while the remaining participants were working individuals of different professions. All participants reported normal hearing and normal or corrected-to-normal sight.



**Fig. 1.** Theoretical assumptions on the associations of speed- and capacity-related aspects of psychometric intelligence with temporal discrimination (TD) and non-temporal discrimination (NTD) in Model 1 as well as general discrimination ability (GDA) in Model 2.

They received EUR 30.00 and feedback was offered about their performance on intelligence testing.

### 2.2. Measurement of psychometric intelligence

Higher TRP is assumed to lead to higher *speed* and *efficiency* of information processing and, thus, should have the most direct and strongest impact on capacity- and speed-related aspects of intelligence. Therefore, for psychometric assessment of individual levels of capacity- and speed-related aspects of intelligence, 12 subtests of the Berlin model of intelligence structure (BIS) test (Jäger, Süß, & Beauducel, 1997) were used to measure both these aspects of intelligence by two verbal, two numerical, and two figural subtests each (see Table 1). *Capacity* resembles the reasoning facet of intelligence, while *Speed* refers to tasks which are extremely easy so that speed of processing is the source of individual differences. More information about the BIS concept and its validity is provided, for example, by Bucik and Neubauer (1996) or Süß, Oberauer, Wittmann, Wilhelm, and Schulze (2002).

### 2.3. Experimental tasks

Four temporal and three non-temporal sensory discrimination tasks were used. For quantification of individual discrimination performance, except for the temporal-generalization task, an adaptive psychophysical procedure, the weighted up-down method (Kaernbach, 1991), was applied. 'Adaptive' means that the difference in stimulus magnitude between the constant standard stimulus and the variable comparison stimulus is varied from trial to trial depending on the participant's previous response. Correct responding results in a decrease of the difference between standard and comparison stimulus and incorrect responding makes the task easier by increasing this difference. A detailed description of this procedure and some details about reliability and validity of the employed tasks are given by Rammsayer and Brandler (2007). On all experimental tasks, participants indicated their decision by pressing one of two designated response keys. The instructions emphasized accuracy not speed.

*Temporal generalization (TG).* A temporal-generalization task with a base duration of 75 ms was applied. The stimuli were sine-wave tones presented through headphones at an intensity of 67 dB SPL. The standard duration was 75 ms, the nonstandard stimulus durations were 42, 53, 64, 86, 97, and 108 ms. In an initial learning phase, the standard interval was presented five times to be memorized by the participants. On each trial of the immediately following test phase, a single duration stimulus was presented. Participants had to decide whether or not the presented stimulus was of the same duration as the memorized standard stimulus. The test phase consisted of eight blocks. Within each block, the standard duration was presented twice, while each of the six non-standard intervals was presented once. All duration stimuli were presented in randomized order. As a measure of performance on temporal discrimination, an index of response dispersion (McCormack, Brown, Maylor, Darby, & Green, 1999) was computed by dividing the relative frequency of 'standard' responses to the standard duration by the sum of the relative frequencies of 'standard'-responses to all seven stimulus durations presented.

*Duration discrimination (DD).* Stimuli were a constant 50-ms standard interval and a variable comparison interval. Onset and offset of the intervals were marked by 3-ms clicks presented binaurally through headphones at an intensity of 88 dB. The task contained 64 trials, and each trial consisted of one standard and one comparison interval. The duration of the comparison interval varied according to the weighted up-down method. To initiate a trial, the participant pressed the space bar; auditory presentation began 900 ms later. The two intervals were presented with an interstim-

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