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Speed- and accuracy-related measures of an intelligence test are differentially predicted by the speed and accuracy measures of a cognitive task

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ABSTRACT

Raw scores on time-limited multiple-choice intelligence tests are determined by incorrect responses and missing answers. Both these error types were previously found to be negatively related to each other. Individual differences in the emphasis on speed or accuracy can explain this finding. But even though individual differences in the emphasis on speed or accuracy have been identified not only in intelligence tests but also in cognitive tasks, little is known about their interplay. Therefore the aim of the present study was to investigate to what degree speed- and accuracy-related performance scores of an intelligence test can be predicted by speed and accuracy measures of cognitive tasks, respectively. For this purpose, 200 participants completed Cattell's Culture Fair Intelligence Test (CFT 20-R) and performed the Swaps Task, an experimental cognitive task. To investigate the interplay between the speed and the accuracy measures of both kinds of task, a latent variable approach was used. Overall, the emphasis on speed or accuracy was not systematically related to the intelligence score. However, closer inspection of the data revealed that reaction times, but not errors rates, in the Swaps Task predicted the number of not-reached items as an indicator of speed in the CFT 20-R. At the same time, error rates, but not reaction times, in the Swaps Task predicted incorrect responses as an indicator of accuracy in the CFT 20-R. Taken together, speed- and accuracy-related performance scores of an intelligence test were predicted by speed and accuracy measures of a cognitive task, respectively. Most important, however, the finding that the emphasis on speed or accuracy was not significantly related to intelligence scores clearly indicated that this emphasis does not interfere with the validity of the intelligence test.

1. Introduction

Ability in classical test theory is commonly based on the number of correctly solved items and determined by two types of errors, the number of incorrectly solved items and missing responses (Moosbrugger & Kelava, 2012). Nevertheless, most previous research in classical test theory did not distinguish between those two error types. In contrast, in item response theory, missing responses are often distinguished from incorrectly solved items (e.g. Köhler, Pohl, & Carstensen, 2015; Ludlow & O'Leary, 1999; Pohl, Gräfe, & Rose, 2014). In that context, not every item has to be presented to each participant (Wainer, 2000). Accordingly, researchers have to decide whether they take missing responses into account or whether they treat them as not administered (Köhler et al., 2015; Ludlow & O'Leary, 1999; Pohl et al., 2014). That decision may influence the estimation of ability as well as the estimation of item difficulty (Ludlow & O'Leary, 1999). Although the importance of separating missing responses from incorrectly solved items is well investigated in item response theory, little is known about the differential predictive power of those two error types in tests following the classical test theory.

Must and Must (2013) reported a negative relation between the number of incorrect responses and missing responses in a time-limited intelligence test. Participants with more incorrect responses showed less missing responses, whereas those with fewer incorrect responses showed more missing responses. Accordingly, higher test scores were achieved due to either fewer incorrect responses or fewer missing responses but not necessarily due to both types of errors at the same time. In other words, the same test scores can be achieved by three different types of test-taking behavior: (1) some incorrect responses and some missing responses, (2) numerous incorrect responses and few missing responses, or (3) few incorrect responses and numerous missing responses.

The negative relation between incorrect and missing responses reported by Must and Must (2013) can be explained by individual differences in the emphasis on speed or accuracy. Participants with an emphasis on speed are faster, show fewer missing responses, but, at the same time, sacrifice accuracy by showing more incorrect responses. On the other hand, participants with an emphasis on accuracy show fewer incorrect responses, but sacrifice speed by showing more missing responses.

Such an emphasis on speed or accuracy should not be confused with the speed-accuracy trade-off (Phillips & Rabbitt, 1995). The speed-

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accuracy trade-off is a phenomenon relating the speed of a response to its accuracy (for a recent review see Heitz, 2014). The more time a participant takes to respond to an item, the greater the accuracy of his/her response. The speed-accuracy trade-off depends on the individual level of mental ability (Phillips & Rabbitt, 1995). More precisely, to respond to an item of an intelligence test, a less able participant is expected to spend more time than a more able participant to reach the same level of accuracy. At the same time, the less able participant is also more likely to sacrifice accuracy to a higher degree for obtaining the same level of speed as a more able participant.

It is hard to disentangle the variance due to ability, which determines the speed-accuracy trade-off from the variance due to the emphasis on speed or accuracy in speed and accuracy indices as both sources of variance are intermixed. For example, high speed might be a result of high ability, a strong emphasis on speed while sacrificing accuracy or of both sources at the same time. The emphasis on speed or accuracy can be considered a dispositional trait rather than an ability. Irrespective of their levels of ability, participants might emphasize speed at the expense of accuracy or accuracy at the expense of speed. If this assumption is true, the emphasis on speed or accuracy should not be systematically related to the raw score of an intelligence test.

In an attempt to isolate the emphasis on speed or accuracy in intelligence tests, Phillips and Rabbitt (1995) calculated the difference between the *z*-standardized speed and accuracy indices of the intelligence measures they obtained. The idea behind this difference approach was first introduced by Salkind and Wright (1977).

As an indicator of accuracy, Phillips and Rabbitt (1995) used the ratio of the number of correct responses to the number of items attempted while Salkind and Wright (1977) among others (e.g. Ackerman & Ellingsen, 2016; Goldhammer, 2015) used the number of incorrect responses. As an indicator of speed, Phillips and Rabbitt (1995) used the number of items attempted, whereas Salkind and Wright (1977) as well as others Ackerman & Ellingsen, 2016; Goldhammer, 2015) used the response latencies.

Proceeding from the assumption that the negative relation between incorrect and missing responses reported by Must and Must (2013) can be explained by individual differences in the emphasis on speed or accuracy, in the present study, accuracy is indicated by the number of incorrect responses and speed by the number of missing responses. Missing responses can be further subdivided into responses that were intentionally omitted and responses that could not be performed due to the time limit of the test. As very few intentionally omitted responses existed in the present study (on average 1% of all responses compared to 8% for not-reached items and 15% for incorrect responses), only the number of not-reached items were considered. The number of not-reached items is perfectly negatively related to the number of items attempted, which is the indicator of speed used by Phillips and Rabbitt (1995).

Individual differences in the emphasis on speed or accuracy are probably influenced by the speededness of the test." Speededness refers to the situation where the time limits on a standardized test do not allow substantial numbers of examinees to fully consider all test items" (Lu & Sireci, 2007, p. 29). Various methods for estimating speededness have been proposed (see Estrada, Román, Abad, & Colom, 2017). One of the most commonly used methods for estimating speededness is based on the proportion of not-reached items in the total number of errors (Stafford, 1971). More recent methods are based on response latencies (e.g. Kahraman, Cuddy, & Clauser, 2013; Lee & Chen, 2011), or on a speed factor that occurs besides the ability factor when analyzing binary data (correct/incorrect) (Estrada et al., 2017; Ren, Wang, Sun, Deng, & Schweizer, 2018). In the present study, test speededness might be imposed by the time limit so that participants adopt a certain emphasis on either speed or accuracy. While, due to the scarce time, participants with an emphasis on accuracy show few incorrect responses but do not reach the last items of the test, participants with an emphasis on speed show few not-reached items but sacrifice accuracy as indicated by many incorrect responses. Accordingly, both the number of incorrect responses as indicator of accuracy as well as the number of not-reached items as indicator of speed might be influenced by the speededness of the test.

Speed and accuracy components could be identified not only in intelligence tests (Goldhammer, 2015; Jeon, 2015; Wilhelm & Schulze, 2002), but also in cognitive tasks (Schweizer, 1996). This, however, does not hold for all kinds of cognitive tasks, as some are of such a low demand that errors are rather unlikely to occur (Jensen, 2006). Due to the very few errors in such low demanding tasks, the speed component can properly be measured as it is not confounded with accuracy. In latter case, the speed component is related to intelligence (Jensen, 2006). In more demanding tasks, a transition takes place from the speed-intelligence correlation to an accuracy-intelligence correlation (Schweizer, 1996). As the speed-intelligence correlation declines, the accuracy-intelligence correlation increases with increasing task demands. It is important to note though, that changes in speed-intelligence and accuracy-intelligence correlations as a function of task demands within this transition zone are poorly understood yet (Dodonova & Dodonov, 2013; Vigneau, Blanchet, Loranger, & Pépin, 2002).

To the best of our knowledge, it has never been investigated to what extent the emphasis on speed or accuracy is consistent across a psychometric intelligence test and an experimental cognitive task with a speed and an accuracy component each. For example, an emphasis on speed should result in a large number of tackled items with only few not-reached responses and a large number of incorrectly solved items in an intelligence test, as well as in fast reaction times and a high error rate on experimental cognitive tasks. Moreover, when the individual emphasis on speed/accuracy is consistent across a cognitive task and an intelligence test, the speed-related (accuracy-related) measure of the intelligence test could be assumed to be functionally related to the speed (accuracy) measure of the experimental cognitive task. Based on these considerations, the aim of the present study was to investigate to what degree a speed- and/or accuracy-related measure of a psychometric intelligence test can be predicted by a speed and/or accuracy measure obtained by an experimental cognitive task. More precisely, we hypothesized the number of not-reached responses in a psychometric intelligence test to be predicted by the reaction time on an experimental cognitive task, whereas the number of incorrect responses in the intelligence test should be mainly related to the error rate on the cognitive task.

2. Method

2.1. Participants

Participants were 67 male and 133 female volunteers ranging in age from 17 to 30 years (mean ± standard deviation of age: 22.6 ± 2.5 years). To cover a large range of individual levels of psychometric intelligence, 149 participants with upper secondary education and 51 participants without upper secondary education were recruited. Before being enrolled in the study, participants gave their written informed consent. The study was approved by the local ethics committee.

2.2. Intelligence

Intelligence was measured by the short version of the German adaptation of Cattell's Culture Fair Intelligence Test (CFT 20-R; Weiß, 2006). The CFT 20-R consists of four different inductive reasoning tasks (Series, Classifications, Matrices, and Topologies) and can be considered an estimate of an individual's general fluid intelligence (Carroll, 1993; Cattell, 1963; Johnson, Nijenhuis, & Bouchard, 2008; Weiß, 2006). Internal consistency of the overall test is 0.92 (Weiß, 2006). On each item of Subtest 1 (Series), a series of three figures is presented. The