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Investigating the relationship of working memory tasks and fluid intelligence tests by means of the fixed-links model in considering the impurity problem

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Abstract

The impurity of measures is considered as cause of erroneous interpretations of observed relationships. This paper concentrates on impurity with respect to the relationship between working memory and fluid intelligence. The means for the identification of impurity was the fixed-links model, which enabled the decomposition of variance into experimental and non-experimental parts. A substantial non-experimental part could be expected to signify impurity. In a sample of 345 participants error scores and reaction times, which were obtained by the Exchange Test, represented working memory, and Advanced Progressive Matrices served as measure of fluid intelligence. The four independent latent variables of the model associated with error scores and reaction times led to a multiple correlation .67 with the latent variable of fluid intelligence. However, there was impurity since the decomposition by means of the fixed-links model showed that only 45% of the common variance was due to working memory.

Keywords: Cognitive process; Fluid intelligence; Structural equation modeling; Latent curve model

The question of whether working memory contributes to intelligence has stimulated a large number of studies. As consequence, many correlational results suggesting the existence of a substantial relationship are available. Ackerman, Beier and Boyle (2005) report a metaanalytic investigation of 57 studies and suggest a correlation of .48. The inspection of the individual results reveals that this field of research shows a high degree of heterogeneity. There are rather low besides very high correlations. The results obtained by means of structural equation modeling are most impressive. Some studies even suggest near identity of working memory and intelligence with respect to individual differences. Typically, the relationship is investigated at the latent level in considering a number of (slightly differing) measures (e.g., Buehner, Krumm, & Pick, 2005; Colom, Abad, Rebollo, & Shih, 2005; Colom, Rebollo, Palacios, Juan-Espinosa, & Kyllonen, 2004; Colom & Shih, 2004; Engle, Tuholski, Laughlin, & Conway, 1999; Kyllonen & Christal, 1990).

The heterogeneity of results demands for an explanation. Actually, there is a number of potential explanations. For example, the difference between correlations observed at the manifest level on one hand and at the latent level on the other hand provides an

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explanation. Different degrees of similarity between the measures for the assessment of working memory on one hand and of intelligence on the other hand give rise to another explanation (Schweizer, 2005). Samples originating from different populations, which in varying degrees allow age to act as moderator can also be accepted as explanation since age was found to be an influential source (Salthouse, 2005). Furthermore, there is the impurity of measures as explanation. There may be different degrees of impurity. If impurity is given, one part of the observed relationship is due to the intended source of performance whereas the other part is due to another source. Impurity calls the interpretation of the result into question.

This paper concentrates on the so-called impurity problem with respect to the relationship between working memory and intelligence. It demonstrates that the impurity of measures can lead to an erroneous interpretation of results concerning the relationship. The identification of impurity requires the combination of differential and experimental methodologies as proposed by Cronbach (1957) some time ago. Furthermore, it is necessary to apply a special structural equation model, denoted fixed-links model (Schweizer, 2006a). In the following sections the impurity problem is presented in more detail, the methodology is described and applied to data obtained by means of measures of working memory and fluid intelligence. The investigation of data in considering the impurity problem ends up with the separation of common variance into parts due to the intended source of performance and due to other sources. If the part due to the other sources is negligible, impurity is not a problem.

1. The impurity problem

Measures representing cognitive concepts are normally not pure measures. In analyzing the processes contributing to performance in completing choice reaction time tasks Jensen (1982) came up with four processes: encoding, operation, binary decision and response. In many cognitive tasks the uptake of information is necessary for initiating the process of interest and the conduction of motor processes for terminating processing. However, neither one of these processes is essential for answering the research question. Furthermore, Van Zomeren and Brouwer (1994) argue that completing a test, which measures divided attention, additionally requires alertness, focused attention and sustained attention. This argument is pointing into the direction of the dilemma of attention research. The manifestation of attention includes the taking influence on some of the transformation processes, which constitute information processing. This is especially obvious in complex tasks which require a lot of executive control (Miyake, et al., 2000). As consequence, attention, which is a predictor of intelligence (Schweizer, Moosbrugger, & Goldhammer, 2005), typically contributes to correlations between measures representing transformation processes and measures of intelligence. It is the manifold of processes contributing to performance, which constitute the impurity problem of differential research since performance is almost always due to a number of different processes. Because of this problem the validation of measures is necessary. However, validation can only guarantee that the concept of interest, which the measure is expected to represent, is reflected by the major source of performance.

In experimental research the impurity problem is avoided by means of several provisions of which the most important one is experimental treatment (see Harris, 2003). The comparison of the results obtained for the various treatment levels enables the concentration on the relevant components of measurement. Although the experimental effect may be reflected by a small component of the measurement only, appropriate statistical methods enable its identification. The combination of treatments and statistical methods provides the opportunity to get a grip on the impurity problem. In sum, the experimental methodology including treatments and statistical methods allows the experimental researcher to overcome the impurity problem. The success of this methodology provides the blueprint for an analogical approach within differential research.

It needs to be added that impurity is not a problem which is restricted to ability research. In personality research impurity was already identified as an annoyance a long time ago. In this field of research the multitrait–multimethod approach (Campbell & Fiske, 1959) was proposed in order to identify impurity. The core of this approach is the multitrait–multimethod design. Furthermore, structural equation modeling has been applied for improving the quality of measurement. Since neither the multitrait–multimethod design nor structural equation modeling alone proved to be sufficient with respect to the impurity problem, this approach was combined with structural equation modeling (Kenny & Kashy, 1992). Although the multitrait–multimethod approach is intriguing, in the field of cognitive ability it is inappropriate since often a specific method of measurement is characteristic for the corresponding concept. As a consequence, a comparison of methods is not possible.