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Contextual analysis of fluid intelligence ☆

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Abstract

The nature of fluid intelligence was investigated by identifying variables that were, and were not, significantly related to this construct. Relevant information was obtained from three sources: re-analyses of data from previous studies, a study in which 791 adults performed storage-plus-processing working memory tasks, and a study in which 236 adults performed a variety of working memory, updating, and cognitive control tasks. The results suggest that fluid intelligence represents a broad individual difference dimension contributing to diverse types of controlled or effortful processing. The analyses also revealed that very few of the age-related effects on the target variables were statistically independent of effects on established cognitive abilities, which suggests most of the age-related influences on a wide variety of cognitive control variables overlap with age-related influences on cognitive abilities such as fluid intelligence, episodic memory, and perceptual speed.

Keywords: Cognitive abilities, Aging; Working memory; Cognitive control

The finding that nearly all cognitive variables are positively related to one another has been described as one of the most replicated results in psychology (cf. Deary, 2000), and one of the most replicated results in research on aging and cognition is that a very large number of cognitive variables are negatively related to adult age (e.g., Salthouse, 2001a, 2004; Salthouse, Atkinson & Berish, 2003; Salthouse & Davis, 2006; Salthouse & Ferrer-Caja, 2003). Interestingly, these two sets of results are linked because the degree to which a given cognitive variable is related to other cognitive variables (as reflected by the variable's loading on the first principal component in a principal components analysis) has been found to predict the magnitude of the age correlation on the variable (e.g., Salthouse, 2001a,b,c). To illustrate, in an analysis of 30 different data sets, Salthouse (2001a) found a median rank-order correlation of .80 between a variable's loading on the first principal component and the absolute magnitude of the variable's correlation with age. Another intriguing outcome of these analyses was that the variables with the strongest associations with other variables and the strongest associations with age were frequently measures of reasoning or fluid intelligence (Gf).

Relations among cognitive variables are often represented in terms of an organizational structure based on the patterns of correlations. There is considerable agreement that a particularly meaningful correlation-based organization is a hierarchical structure, with observed

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variables at the lowest level, various cognitive abilities at intermediate levels, and a *g* factor at the highest level (e.g., Carroll, 1993; Gustafsson, 1988; Jensen, 1998). A consistent finding of analyses investigating where in the hierarchical structure age-related influences operate is the discovery of significant negative relations of age on the highest-order factor in the structure (e.g., Salthouse, 2004, 2005a; Salthouse & Ferrer-Caja, 2003). Moreover, these and other analyses (e.g., Gustafsson, 1988) have found a very strong relation between the higher-order factor and a Gf factor.

These two sets of results suggest that a key to understanding age-related influences on many different cognitive variables may be understanding the nature of individual differences in Gf. Although the term fluid intelligence is sometimes used to refer to any cognitive variable that is negatively related to age, Cattell (1943), the originator of the term, defined it as the ability to discriminate relations, and it is often conceptualized as influencing the quality of reasoning, novel problem solving, and adaptation to new situations. Publishers of cognitive test batteries that include tests of this construct have provided similar definitions:

> "… Gf is a broad ability to reason.… This capacity is manifested in drawing inferences and comprehending implications. Gf is best measured with tasks that are novel — i.e., those that require one to discover the essential relations of the task for the first time and draw inferences that could not have been worked out before. Tasks intended to measure Gf should not depend heavily on previously acquired knowledge or earlier-learned problem-solving procedures (Woodcock & Mather, 1990, p. 13)."

> " … Gf… is the ability to solve new problems, specifically the type that are not made easier by extended education or intensive acculturation.… Fluid tasks must involve stimuli and concepts that are about equally available to virtually anyone in a culture (Kaufman & Kaufman, 1993, p. 11)."

These definitions are useful in distinguishing Gf from other ability constructs, but they are not very helpful in specifying the precise nature of Gf. A primary goal of the current project was to apply a recently proposed analytical method to attempt to understand the nature of Gf, and its relations to age differences in different types of cognitive variables.

The analytical method used in the current project is termed *contextual analysis* because the meaning of target variables, and the age-related influences on them, are interpreted in the context of established cognitive abilities (Salthouse, 2005b; Salthouse, Siedlecki & Krueger, 2006). Each reference cognitive ability is represented in the analyses as a latent construct defined by the variance common to between 3 and 6 measured variables. When a target variable is regressed on these reference cognitive ability constructs, the magnitudes of the standardized regression coefficients predicting the target variable from the cognitive abilities can be interpreted as reflections of the extent to which the target variable is uniquely related to each cognitive ability. Because several cognitive abilities are used as simultaneous predictors of the target variable, the analytical procedure is equivalent to a set of multiple regression equations, one for each target variable. However, in order to allow the cognitive abilities to be represented as latent constructs, the analyses were conducted with a structural equation modeling program rather than as simple regression analyses. This contextual analysis method has some resemblance to Dwyer's (1937) extension analysis, and is closely related to a procedure described in Salthouse and Ferrer-Caja (2003; also see Salthouse, 2001a).

Among the advantages of this analytical method are that several reference abilities can be examined simultaneously to determine the unique influences of each ability on the target variable, each reference ability is represented as a latent construct that is theoretically free of measurement error, and when the age variable is included in the analyses, age-related effects on the target variable can be decomposed into effects shared with other cognitive abilities and effects that are statistically independent of other abilities. Simultaneous analyses of multiple abilities is important because the magnitudes of the relations on the target variable could be overestimated if several constructs are not included in the analyses. That is, influences shared with other constructs cannot be distinguished from influences that are unique to a given construct when only one construct is considered. Conceptualizing abilities as latent constructs is also important because the magnitudes of the relations may be underestimated if the reference abilities are represented by single variables in which the presence of measurement error may attenuate observed correlations. Finally, because a very large number of cognitive variables has been found to be related to age, cumulative progress can be ensured by establishing that age-related effects on a target variable represent something different from what is already known. That is, when researchers study isolated variables there is no way to determine whether