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On the nature of crystallized intelligence: the relationship between verbal ability and factual knowledge ☆

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ABSTRACT

While crystallized intelligence (g_c) is recognized in many contemporary intelligence frameworks, there is no consensus as to the nature and contents of the construct. Originally conceptualized as capturing acquired skills and declarative knowledge in different content domains, more recent definitions and typical indicators focus on verbal ability. We investigated the relationship between verbal ability and declarative knowledge under consideration of individual differences in fluid intelligence in a large-scale assessment study with 6,701 adolescents. Structural equation modeling was used to examine the factorial distinctness of verbal ability and declarative knowledge with three analytical strategies: (i) Estimating correlations between latent variables, (ii) estimating the amount of unique variance in each factor after accounting for differences in the other ability constructs, and (iii) investigating associations with covariates including school achievement, students' characteristics, and psychological traits. The correlation between latent variables representing verbal ability, measured with items from six language domains, and knowledge in 16 content domains was very high ($\rho = .91$), but significantly different from unity. About 17% of the variance in the knowledge factor was independent of individual differences in verbal ability and fluid intelligence. Associations with covariates revealed unique correlational patterns for each ability construct. The findings suggest that verbal ability and knowledge are closely related, but empirically distinguishable facets of crystallized intelligence. The discussion focuses on the construct validity of verbal tests for the measurement of g_c and the interpretation of the common factor of a broad knowledge assessment as a causal variable.

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1. Introduction

Crystallized intelligence (g_c) is a prominent ability construct in major theories of intelligence structure including the extended Gf-Gc theory (e.g., Horn & Noll, 1997), Carroll's (1993) Three-stratum theory, and the Cattell-Horn-Carroll (CHC) theory of intelligence (e.g., Schneider & McGrew, 2012). However, despite a long research tradition on g_c the content and nature of the construct is still considered "elusive" (Keith & Reynolds, 2010, p. 643) and major intelligence frameworks and test batteries differ in their definition and operationalization of g_c. Whereas Cattell's original definition of crystallized intelligence was very broad, including skills and knowledge in diverse content domains (Cattell, 1943, 1971), the g_c factor in Carroll's (1993) theory is mainly defined by abilities in the domain of language. Recently, Kan, Kievit, Dolan, and van der Maas (2011) argued that the g_c factor in CHC theory may be identical to verbal ability, explicitly excluding knowledge in other domains. This corresponds to the widespread practice of measuring g_c with verbal indicators only (e.g., vocabulary tests) instead of using more diverse knowledge indicators.

In the present study, we take on the perspective of Cattell's original definition of crystallized intelligence and its emphasis on knowledge. We argue that a comprehensive

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measurement of g_c should sample knowledge from various domains, including but not limited to language-related knowledge, because verbal ability and factual knowledge are closely related but factorially distinct facets of the g_c construct. We test this assumption empirically by investigating the relationships between verbal ability, factual knowledge, and – because it is assumed to be an important factor in the development of crystallized abilities (Cattell, 1971) – fluid intelligence (g_f) using data from a large-scale educational assessment study. Since empirically distinct constructs should differ in their relationships to relevant covariates (Brunner, 2008; Horn, 2008), we also explore the associations of verbal ability, knowledge, and g_f with school achievement, students' characteristics, and other psychological constructs.

The introduction is structured as follows. First, we give an overview of the different conceptualizations of crystallized intelligence in influential intelligence theories. Second, we review factor-analytic evidence concerning the distinction between knowledge and verbal ability. The subsequent section focuses on associations with covariates. Finally, we summarize the research questions.

1.1. Knowledge and verbal ability in definitions of crystallized intelligence

The term "crystallized intelligence" was introduced by Cattell (1943) who initially distinguished between two broad factors of intelligence: Whereas fluid intelligence (g_f) "shows itself in successfully educing complex relations among simple fundaments whose properties are known to everyone", crystallized intelligence "operate[s] in areas where the judgments have been taught systematically or experienced before" (Cattell, 1971, p. 98). This broad definition of g_c as capturing the influences of learning, education, and acculturation in various domains including language is most clearly reflected in Cattell's considerations about the measurement of crystallized intelligence in adults. Since with increasing age potential learning opportunities become more diverse, a comprehensive assessment of g_c in adulthood would require "[sampling] behavior still more widely (…) [,] an approach which, in practice, might amount to producing as many different tests as there are occupations, etc." (Cattell, 1971, p. 121). Gf-Gc theory was extended later on to include other ability constructs besides g_f and g_c (e.g., Horn, 1988; Horn & Noll, 1997). Consistent with the original focus on knowledge, Horn (2008, p. 197) described g_c as a prominent ability factor that captures acculturated knowledge with tasks "indicating breadth and depth of knowledge of the language, concepts, and information of the dominant culture". It can be argued that the g_c factor in the extended Gf-Gc theory is slightly narrower than Cattell's original definition because knowledge in mathematics is captured with a separate quantitative knowledge factor g_q. In the Cattell-Horn framework typical g_c indicators included knowledge tests and verbal tests (e.g., vocabulary measures). Concerning more specific language skills such as spelling or grammar, Horn (1988) speculated that these skills may capture a factor separate from g_c.

In his Three-stratum theory based on a review and reanalysis of 461 data sets on cognitive abilities, Carroll (1993) understood g_c and g_f as broad ability factors on the second stratum, that is, below the general intelligence factor. While Carroll (1993) also documented the high loadings of knowledge tests on the g_c factor, he defined it primarily in terms of language-related abilities. This is evident when inspecting the stratum I factors below g_c which include "Verbal or printed language comprehension (V)", "Lexical knowledge (VL)", "Reading comprehension (RC)", "Cloze ability (CZ)", "Spelling ability (SG)", "Grammatical sensitivity (MY)", "Listening ability (LS)", "Writing ability (WA)", and several others (Carroll, 1993, chapter 5). However, Carroll (1993) repeatedly pointed out the close association between language measures, especially vocabulary tests, and knowledge tests. He speculated that this relationship may be due to similarities in the operationalizations and similar acquisition processes (i.e., both lexical knowledge and factual content knowledge are learned through reading, inference, etc.). On the other hand, he asserted that this relationship is not a logical necessity "since it is conceivable that a person could acquire good language comprehension without necessarily acquiring general information" (Carroll, 1993, p. 153).

An intelligence framework that explicitly distinguishes between certain language skills and factual knowledge is the Cattell-Horn-Carroll (CHC) theory (e.g., McGrew, 2009; Schneider & McGrew, 2012), a synthesis and extension of the Three-stratum theory and the extended Gf-Gc theory. Acquired skills and knowledge are represented by as much as four different broad (i.e., second-stratum) constructs in the CHC framework: g_c, g_{kn}, g_q, and g_{rw}. The g_c factor resembles the knowledge-related definition by Cattell and Horn as it captures "the knowledge of the culture that is incorporated by individuals through a process of acculturation" (McGrew, 2009, p. 5), including knowledge of word meanings. As in the extended Gf-Gc theory, quantitative knowledge is captured in a separate factor g_q. Also, domain-specific 'expertise' knowledge is not part of g_c, but represented by a construct designated g_{kn}. However, CHC theory is vague with regard to the definition of 'expertise', stating that it is "specialized (…) knowledge not all members of a society are expected to have" (Schneider & McGrew, 2012, p. 123) which seems to be contradicted by several narrow factors defining g_{kn} such as "Knowledge of culture (K2)" and "General science information (K1)" (p. 125). Language-related knowledge and abilities are captured by g_c and g_{rw}. Whereas oral language skills such as listening ability are represented by g_c – which is consistent with Carroll's (1993) g_c factor – "both basic skills (e.g., reading and spelling of single words) and the ability to read and write complex connected discourse" are captured by a separate reading-writing factor g_{rw} (McGrew, 2009, p. 6). Hence, the g_c factor in the CHC framework is described as a mixture of knowledge and oral language skills, whereas g_{rw} represents written language skills such as reading, spelling, writing, and cloze ability. It has to be stressed that all four CHC factors discussed here are covered by Cattell's original definition of crystallized intelligence. Acknowledging this, Schneider and McGrew (2012, p. 128) believed "that it is useful to think of a higher-order acquired-knowledge/expertise factor that unites Gc, Grw, Gq, and Gkn".

1.2. Factor-analytic evidence for the distinction between knowledge and verbal ability

Currently, evidence for the distinction between g_c and g_{rw} as defined in CHC theory is scarce. Woodcock (1998) used

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