



Visual-object ability: A new dimension of non-verbal intelligence

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ARTICLE INFO

Article history:

Received 9 August 2009

Revised 13 August 2010

Accepted 27 August 2010

Keywords:

Visual imagery

Intelligence

Visual-object ability

Visual-spatial ability

ABSTRACT

The goal of the current research was to introduce a new component of intelligence: visual-object intelligence, that reflects one's ability to process information about visual appearances of objects and their pictorial properties (e.g., shape, color and texture) as well as to demonstrate that it is distinct from visual-spatial intelligence, which reflects one's ability to process information about spatial relations and manipulate objects in space. Study 1 investigated the relationship between performance on various measures of visual-object and visual-spatial abilities, and areas of specialization (visual art, science and humanities). Study 2 examined qualitative differences in approaches to interpreting visual abstract information between visual artists, scientists and humanities/social science professionals. Study 3 investigated qualitative differences in visual-object versus visual-spatial processing by examining how members of different professions generate, transform, inspect, and manipulate visual images. The results of the three studies demonstrated that visual-object ability satisfies the requirements of an independent component of intelligence: (1) it uniquely relates to specialization in visual art; (2) it supports processing of abstract visual-object information; and (3) it has unique quantitative and qualitative characteristics, distinct from those of visual-spatial processing.

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1. Introduction

The notion of intelligence and its internal structure has been constantly changing throughout the last century. Historically, the definition of intelligence has moved from describing it as a general unitary entity with specific properties (Spearman, 1904) to describing it as a combination of multiple components (e.g., Sternberg, 1985; Thurstone, 1938) although not necessarily rejecting a common underlying factor, such as general intelligence (*g*). Overall, the mainstream definition of intelligence (Gottfredson, 1994, p. A18) describes it as “a mental capacity that involves

the ability to reason, plan, solve problems, think abstractly, comprehend complex ideas, learn quickly and learn from experience”, (see also 1997,² p. 13). Despite their differences in distinguishing components of intelligence, the existing approaches to the study of intelligence suggest that, in order to define a mental capacity or ability as an intelligence construct, it must meet the following principal requirements: (1) the ability must play a functional role, that is, it must be related to performance on complex tasks, such as educational or occupational tasks, and not just reflect a certain narrow ability, such as the ability to score highly on academic tests or perform laboratory tasks of low ecological value (Gardner, 1999; Gottfredson, 1997;

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² Gottfredson's “Mainstream Science on Intelligence” (1994) proposed a definition of intelligence signed by 51 prominent professors in the field of intelligence research. The paper was first published in the *Wall Street Journal*, and the reprinted in *Intelligence* with additional information and references (1997).

Lubinsky, 2004; Sternberg, 1985), (2) it must support high-level information processing, such as abstract representations or symbolic encoding (Carpenter, Just, & Shell, 1990; Galton, 1880; Gardner, 1999; Gottfredson, 1997; Snyderman & Rothman, 1987), and (3) it must have unique qualitative and quantitative characteristics, supported by behavioral and/or neurological evidence, that distinguish it from other components of intelligence (Gardner, 1999). The focus of the current paper is to introduce a new dimension of intelligence: *visual-object intelligence*, which reflects one's ability to process information about the visual appearances of objects and their pictorial properties (e.g., shape, color and texture). This component of intelligence has so far been largely neglected and ill-defined, and the current research seeks to show that visual-object ability has all of the above attributes that characterize a dimension of intelligence.

Currently, the only widely accepted component of visual intelligence is *visual-spatial* ability, which is included in most commonly used measures of intelligence (e.g., Stanford-Binet: Roid, 2003, Wechsler Intelligence Scale: Wechsler, 1997). Visual-spatial ability represents a number of related subcomponents (e.g., spatial visualization, spatial relations) that have to do with how individuals deal with materials presented in space, or with how individuals orient themselves in space (Carroll, 1993). It was isolated from general intelligence and from verbal and numerical factors only after the 1920s, based on the results of factor analysis correlations among different intelligence tests (Smith, 1964). Subsequently, tests of spatial ability have been proven to be important criteria for predicting students' achievement in mathematics and a wide range of technical areas (see McGee (1979) for a review), and in predicting performance in engineering, mechanics and physics (Ghiselli, 1973; Hegarty & Just, 1989; Holliday, 1943; Kozhevnikov & Thornton, 2006; Smith, 1964). Beginning in the 1980s, cognitive psychology research has further characterized processing differences between individuals with high versus low visual-spatial ability for solving such spatial tasks as mental rotation (Carpenter, Just, Keller, Eddy, & Thulborn, 1999), mechanical, physics, and engineering problems (Hegarty & Just, 1989; Kozhevnikov, Motes, & Hegarty, 2007). These studies suggested that spatial ability is related to spatial working memory capacity as well as available central executive resources (see also Miyake, Friedman, Shah, Rettinger, & Hegarty, 2001). Thus, spatial ability was found to have all the essential characteristics of intelligence: ecological validity, capacity to support abstract spatial processing in engineering and scientific fields, as well as unique qualitative and quantitative characteristics supported by cognitive psychology research.

At the same time, other non-spatial components of visual ability have been neglected. Although factor analytical studies have revealed a number of visual ability factors, separate from spatial ability factors, such as the ability to apprehend and identify visual patterns or shapes in the presence of distracting stimuli (Closure Flexibility and Closure Speed factors; Carroll, 1993), they were considered only as minor factors whose predictive validity and relation to visual-spatial ability were unclear (e.g., Lohman, 1979). Furthermore, the ability to generate vivid colorful images of objects and scenes, as measured by the Vividness of Visual Imagery

Questionnaire (Marks, 1973), was long thought to represent an aspect of visual-spatial ability, rather than constitute a separate imagery skill, despite the fact that the instruments assessing individual differences in imagery vividness have failed to establish significant correlations with spatial tasks (for review, see McKelvie, 1995).

Only recently has cognitive neuroscience provided strong evidence that visual processing of object properties is distinct from visual processing of spatial properties. Since the 1990s, it has been shown that higher-level visual areas of the brain are divided into two functionally and anatomically distinct pathways: the object pathway, and the spatial relations pathway (e.g., Kosslyn & Koenig, 1992; Ungerleider & Mishkin, 1982). The object (occipito-temporal or ventral) pathway processes information about the visual pictorial appearances of individual objects and scenes, in terms of their shape, color, brightness, texture, and size, while the spatial relations (occipitoparietal or dorsal) pathway processes information about the spatial relations among, and movements of, objects and their parts, and complex spatial transformations. The distinction between perceptual processing of object properties versus spatial relations extends to visual mental imagery and working memory (Farah, Hammond, Levine, & Calvanio, 1988; Kosslyn, 1994; Kosslyn & Koenig, 1992; Levine, Warach, & Farah, 1985; Mazard, Tzourio-Mazoyer, Crivello, Mazoyer, & Mellet, 2004). For example, Levine et al. (1985) demonstrated that lesions to temporal cortex disrupt performance on a spatial imagery task, but not on an object imagery task. In contrast, lesions to posterior parietal cortex have the reverse effects (see also Farah et al., 1988). Furthermore, recent evidence suggests that the visual-spatial sketchpad component of working memory consists of separate visual (object) and spatial subcomponents (Logie, 2003; Logie & Marchetti, 1991), which are underpinned by separate dorsal and ventral functional organizations, respectively (Courtney, Petit, Maisog, Ungerleider, & Haxby, 1998). The above object-spatial double-dissociation emphasizes that visual-object processing is functionally and anatomically independent from visual-spatial processing.

Recent research has also provided support for distinctions between visual-object and visual-spatial processing at the individual differences level (Kozhevnikov, Hegarty, & Mayer, 2002; Kozhevnikov, Kosslyn, & Shephard, 2005). Kozhevnikov et al. (2005) identified two types of individuals based on their imagery abilities: individuals with high object-imagery ability, called object visualizers, and individuals with high spatial-imagery ability, called spatial visualizers. While object visualizers used imagery to construct high-resolution images of the visual properties (e.g., shape and color) of individual objects and scenes, spatial visualizers used imagery to represent and transform spatial relations (e.g., location and configuration). It has also been shown that, in contrast to visual-spatial ability, which is associated with more efficient use of spatial resources in the dorsal pathway (Lamm, Bauer, Vitouch, & Gstattner, 1999; Vitouch, Bauer, Gittler, Leodolter, & Leodolter, 1997), visual-object ability is associated with more efficient use of visual-object resources in the ventral pathway (Motes, Malach, & Kozhevnikov, 2008).

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