Intelligence Assessment for Visual Information Design Research

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Abstract: The effectiveness of design objects relies on their interaction with humans. This fact builds a direct relationship between psychology and design. Particularly, the effectiveness of visual information relies on how people process information. This implies that visual information design research needs an approach to understand human abilities and capacities for verbal and visual information processing. They can be measured using two major contemporary psychological approaches to human intelligence: the general intelligence theory and the multiple intelligence theory. This paper discusses the differences between these theories and how either one can be applicable in visual information design research settings. Alternatives based on these theories are suggested to apply intelligence assessment in visual information design research with their possible strengths and weaknesses. The implications of intelligence for design are the definition of how human abilities affect quality and performance of visual information and, hence, how visual information should be designed to fit different human intelligence levels or profiles.

Key words: visual ability, verbal ability, assessment, information design, visual design, multiple intelligences theory, general intelligence theory, CHC theory.

1. Introduction

Today is the age of visual culture. The "screen-based" world has increased the awareness of visual structures to deal with complex information and literacy (Felten, 2008). Visual information can be easily used for different kinds of knowledge in different media; however, complex knowledge is still mostly stored in verbal textual format. The psychological theories of intelligence support the premise that there are differences in human ability and capacity in verbal and visual processing. Therefore, the assessment of difference levels of visual and verbal intelligence are relevant in the field of information design where the aim is to convert, combine, and create knowledge using visual and verbal information. This awareness of differences among individuals and contexts has become essential in design practice. Still, designers rely primarily on intuitive principles when creating objects and spaces. They do not know much about the visual information processing (Zender, 2007). One reason for this is that traditional design education and practice was centered on learning by imitation of a master teacher, which is insufficient for the current complex challenges of design (Buchanan, 2004). Research is needed to define specific aspects of information design to make it more useful and precise in responding to different individuals and contexts. This paper examines the potential to assess visual and verbal intelligence using two major intelligence theories to study the design efficiency of visual information: general intelligence theory and multiple intelligences theory.

Design has measured intelligence of designers but not of users (See for example Ho et al., 2005; Tomes et al., 1998; Purcell and Gero, 1998). Cross (2006; 1990) has found that designers nurture what he calls "design ability", which has the following narrow capacities: formulation of problems, generation of solutions and processing of strategies. On the other hand, near fields of information visualization and human-computer interaction have used general intelligence to study human abilities of users and their relation with information and interfaces. In information visualization field, Chen (2006) surveyed experiments in cognitive abilities done between 1991 and 2000. He described experiments with associative memory, spatial ability, and visual memory; but he said that a conclusive meta-analysis is not possible due to the limited amount of research.

In human-computer interaction field, Dillon and Watson (1996) presented the importance of individual differences to obtain "predictive power" in the design of systems. Recently, Cockburn and McKenzie (2004) compared spatial memory between two and three-dimensional displays and conclude that the later does not assist users' spatial memory. Pak et al. (2006) studied the influence of spatial ability in navigation. They found that spatial orientation ability is predictor of human performance but spatial visualization is not. Pak and Price (2008) compared taxonomy with tag-based information retrieval systems, observing performance differences in young and older adults, they observed that tag-based system reduces performance difference between ages. Downing et al. (2005) observed visual ability as a predictor of performance in computer information search tasks comparing students of biology and business. They found that both visual ability and domain precedence are predictors of seeking tasks. While these findings alone are significant for visual information design, it is important to note that they focus on human performance rather than the quality of information or interface design, which are important to information performance. Indeed, critical issues like the quality of the visual information and the aesthetic level of refinement in the measurement tools are usually disregarded.

To continue with the analysis of intelligence assessment for visual information design, it is convenient to clarify the assumption that guides this work. It could seem that high visually intelligent humans would process better visual information and verbally intelligent humans would process better verbal information; yet, the hypothesis is that both visually and verbally intelligent humans process visual information faster than verbal information. As a consequence, this examination does not try to divide humans between verbal information for verbally intelligent individuals and visual information for visually intelligent individuals. Instead, this exploration looks for ways in which the measurement of different profiles of visual and verbal intelligence can be used to obtain knowledge applicable to validation or redefinition of design principles for effective communication. Also it is necessary to clarify that this paper bases its analysis only on cognitive abilities and does not include cognitive styles or learning styles. A comprehensive study of visual and verbal dimensions that includes cognitive abilities, cognitive styles, and learning styles can be found in Meyer and Massa (2003).

2. Intelligence Theories

This paper examines two major theories of intelligence: the Catell-Horn-Carroll theory of cognitive abilities (CHC, McGrew, 2005; Carroll, 1993), which reaches all previous theories of general intelligence, and the Multiple Intelligence theory (MI, Gardner, 2006; Gardner and Chen, 2005; Gardner 1995; 1983). Both of them recognize a difference between verbal and visual cognitive processing. The theory of cognitive abilities is a survey done by Carroll (1993) to include all cognitive abilities described by previous psychology theorists including Turnstone, Guildford, Catell, Horn, and Wechsler. It is based on several decades of psychometric assessment of intelligence. Today the theory is known as Catell-Horn-Carroll theory of cognitive abilities. CHC theory consists of three stratums of cognitive abilities: stratum I of narrow abilities, stratum II of broad abilities, and stratum III of general ability (*g*) (Carroll, 1993). Initially, Carroll (1993) determined the first stratum of narrow abilities from more than sixty years of experimental research of intelligence. And McGrew (2005), based on new experimental research, updated the theory, which has had some changes in broad and narrow abilities. Currently, the second stratum of broad abilities includes two that are closely related with this analysis: broad visual-spatial abilities (Gv) and general reading/writing (Grw).

In the other hand, MI theory neglects the existence of a general intelligence and contends that human beings have different profiles among independent intelligences: linguistic, logical-mathematical, musical, visuo-spatial, bodily-kinesthetic, naturalistic, interpersonal, and intrapersonal (Gardner, 2006). Each independent intelligence must comprise a required criteria: potential isolation by brain damage, existence of exceptional individuals, existence of a core of information processing operations, identifiable developmental history, existence of evolutionary history, support from experimental psychology, support from psychometric findings, and a symbol system (Gardner, 1983). Chen and Gardner (2005) explained that everyone has an intelligence profile shaped by influences of the culture, and individual decisions. Intelligences have an initial biological condition but can be fostered by developmental, neurological, psychological and cultural factors. Thus, each individual person develops a virtual profile of strengths and weaknesses. Two of these intelligences are related to this analysis: linguistic for verbal information processing and visuo-spatial intelligence for visual information processing.

3. Intelligence Assessment

Assessment with CHC theory is done with norm-based test compatible with a quantitative research approach. Contemporary psychometrical tests have been revised and created for interpretation with CHC theory, whose assessment is quantitative (See for example Schranck, 2006; and Reynolds and Kamphaus, 2005). The theory itself has been built by cumulative research in quantitative intelligence assessment with countless studies of reliability and validity. Contemporary batteries of intelligence measurement extensively determine correspondence with this theory to found interpretations and revise new versions (Alfonso et al., 2005). For Matthews et al. (2000) CHC theory is the most valid theory to use in intelligence assessment. They said that psychometric tests ensure accuracy in research.

Nonetheless, Chen and Gardner (2005) pointed out some difficulties. First, psychometric tests are based on primarily verbal code, which is not fair with non-linguistic capacities. Second, some abilities are wrongly measured horizontally and they should be measure vertically. For example, processing speed is measured horizontally across different abilities, but they may vary according the attributes of different intelligences. Third, the intent of psychometric tests to use abstract content to improve accuracy is a mistake because intelligences are not pure and should be measured in familiar context to motivate attention of the individual. Finally, they argue that assessment cannot be "one-shot" experience because it needs "ecological validity" creating a context to continuously inform learning and assessment.

In contrast, MI theory assessment is done with detailed observations in real contexts with specific instruments related with different capacities (Gardner, 2006; Chen and Gardner, 2005), which is compatible with a qualitative approach. This theory has been well accepted in education and there are several references of MI use for instruction (See for example Campbell et al., 1999). Chen and Gardner (2005) explained that assessment and instruction inform and enhance each other, which let an assessor create narrative profiles of intelligence. Nevertheless, Carroll (2005; 1993) criticized MI theory arguing that there is a close relation of eight intelligences with the broad abilities or stratum II. He also says that Gardner neglects the abundant experimental research in intelligence that shows evidence about a general intelligence. Visser et al., (2006) conducted a study where they selected and applied two objective ability tests for each multiple intelligence. They found that only bodily-kinesthetic, musical, and intrapersonal intelligences are not correlated with general intelligence; but the general intelligence measuring tools used are rejected by MI theory. Additionally, MI theory makes it difficult to measure reliably since the assessment itself is considered continuously modifiable in the individual adaptation process in the context. Most of the theory has been developed for instruction where educators can be natural ethnographers to hold such sort of assessment. For these reasons there are not yet recognized tools for other practices like human factors, personal selection or design.

As alternative of the prescribed assessments commonly use behind these theories, there are options to assess intelligence. One is the emergent trend of cross-battery assessment to assure a complete estimation of cognitive abilities classified in the CHC theory (Alfonso et al., 2005). This method means that any battery or test is enough to measure all the range of cognitive abilities; however, it is unpractical for design research that is usually not longitudinal. Another option is the use of self-estimates of intelligence, which is applicable to both theories. This indicator of intelligence has been largely study and correlated with general and multiple intelligences theories giving diverse results (Chamorro-Premuzic and Furnham, 2005). Ackerman and Wolman (2007) measured correlation of self-estimates with objective tests and although they found a positive correlation, they were not enough to contend that individuals are precise estimating their abilities. They conclude that the accuracy of self-estimation relies on variables and personal traits such as experience, expectation, personality or motivation. In addition, Furnham (2001) surveyed previous research in gender and age in self-estimation of intelligence and found also diverse inconclusive correlations.

3. Assessment of Visual and Verbal Abilities.

For visual information design, Assesment of verbal and visual abilities is relevant because visual information contains both verbal and visual elements. This paper focuses on assessment of verbal and visual information processing since it centers the analysis in user interaction rather than designer creation. This issue is significant as it reduces the amount of abilities to measure. For instance, among verbal abilities reading is relevant as user ability in interaction with information but writing is less relevant. The use of either CHC or MI theory has implications in design research methods. This section examines the possibilities offered by both theories to assess verbal and visual abilities. Tests based on CHC theory have the goal of measure third stratum of general intelligence and are designed mainly for educational and clinical purposes. Then, a measure of only verbal and visual abilities requires the use of subtests. ETS kit factor-referenced cognitive test assess wide range of cognitive abilities (Ekstrom et al., 1976). It was designed between 1952 and 1976 as one of the first attempts to survey correlations among abilities (McGrew, 2009; Carroll, 1993). Although there are more contemporary and revised tests, the kit is currently used in research in different fields like psychology, information visualization, education, or human-computer interaction (See for example Ackerman and Wolman 2007; Visser et al., 2006; Chen 2006; Meyer and Massa, 2003; Pak and Price, 2008; Pak et al., 2006; and Downing et al., 2005). Table 1 shows a proposal of subtest assessment of verbal and visual abilities using ETS kit based on the CHC theory updated by McGrew (2005). For verbal abilities are used the reading narrow abilities of broad Reading/writing ability (Grw) and for visual abilities is used broad Visual-Spatial ability (Gv). The kit presents more strength measuring visual abilities.

Table 1. Proposal of subtest measurement of visual and verbal abilities with ETS kit.

Broad ability	Narrow ability	Kit subtest	Parts of subtest
Reading/ writing (Grw)	Verbal (printed) language Comprehension (V)	V—Verbal Comprehension	Vocabulary, extended range vocabulary, advanced vocabulary
	Cloze Ability (CZ)	CV—Closure, Verbal	Scrambled words, hidden words, incomplete words
Visual-spatial (Gv)	Flexibility of Closure (CF)	CF—Closure, Flexibility of	Hidden figures, hidden patterns, copying.
	Closure Speed (CS)	CS—Closure, Speed of	Gestalt completion, concealed words, snowy pictures.
	Visual Memory (MV)	MV—Memory, Visual	Shape memory, building memory, map memory.
	Spatial Scanning (SS)	SS—Spatial Scanning	Maze tracing speed, choosing a path, map planning
	Spatial Relations (SR)	S—Spatial Orientation	Card rotation, cube comparisons
	Visualization (Vz)	VZ—Visualization	Form board, paper folding, surface development

Moreover, two contemporary norm-based tests, that measure general intelligence, make a clear distinction in how visual and verbal information processing is assessed: Woodcock-Johnson III (WJ-III) and Reynolds Intellectual Assessment Scales (RIAS). WJ-III is a comprehensive test mainly used in education that measures a wide range of broad and narrow abilities. WJ-III bulletin (Shranck, 2006) explains how the test can be interpreted with the CHC theory. Based on this, Table 2 explains a proposal of five narrow abilities from broad visual-spatial abilities (Gv) and four narrow abilities from broad Reading/writing abilities (Grw) that can be tested with WJ-III in order to compare strengths and weaknesses of individuals to process visual and verbal information.

Table 2. Proposal of subtest measurement of visual and verbal abilities with WJ-III (Based on Shranck, 2006).

Broad ability	Narrow ability	WJ-III Correspondence
Reading/ writing (Grw)	Reading decoding (RD)	WJ-III ACH. Test 1: Letter-Word Identification. WJ-III ACH. Test 13: Word Attack.
	Reading Speed (fluency) (RS)	WJ-III ACH. Test 2: Reading Fluency
	Cloze ability (CZ)	WJ-III ACH. Test 9: Passage Comprehension.
	Reading Comprehension (RC)	WJ-III ACH. Test 9: Passage Comprehension. WJ-III ACH. Test 17: Reading Vocabulary.
Visual-spatial (Gv)	Visualization (VZ)	WJ-III COG. Test 3: Spatial Relations. WJ-III COG. Test 28: Block Rotation.
	Spatial Relations (SR)	WJ-III COG. Test 3: Spatial Relations. WJ-III COG. Test 28: Block Rotation.
	Visual memory (MV)	WJ-III COG. Test 13: Picture recognition.
	Spatial scanning (SS)	WJ-III COG. Test 19: Planning.
	Closure speed (CS)	WJ-III COG. Test 22: Visual Closure.

Alternatively, RIAS is a recent test focused on verbal and non-verbal abilities based on CHC theory designed for educational and clinical settings. The aim of the test is provide a reliable, practical, and rapid instrument to measure of general intelligence using its two primary components (Reynolds and Kamphaus, 2005). Table 3 shows the structure of RIAS, whose subtests can be applied completely because the authors referenced the nonverbal test as equivalent of visualization or spatial abilities (Ibid). Still, any subtest can be used for convenience. For example, the Composite Memory Index can be disregarded if it is not significant for the research aims.

Table 3. Structure of RIAS (Reynolds and Kamphaus, 2005).

Index	Subtest group	Subtest
Composite Intelligence Index (CIX)	Subtests Verbal Intelligence Index (VIX)	Guess What: with given clues, deduce objects or concepts. *Abilities: Verbal reasoning with vocabulary, language development.* Verbal Reasoning: with listened statement-analogy complete the idea with 1-2 words. *Abilities: Verbal-analytical reasoning with vocabulary, language development.*
	Subtests Nonverbal Intelligence Index (NIX)	Odd-Item Out: identify in a group of pictures one that do not belong or go with the others. *Abilities: Nonverbal reasoning with spatial, visual imagery skills.* What's Missing: look for an essential component missing in a picture. *Abilities: Nonverbal reasoning.*
Composite Memory Index (CMX)	Subtests	Verbal memory: after sentences/stories are read aloud, ask for recall. *Abilities: Working memory.* Nonverbal memory: after presenting a picture 5 seconds, identify target from an array of 6 pictures. *Abilities: Working memory.*

Although use of partial test selecting subtests might be practical and time convenient in fields like visual information design research, conflicting arguments with the concept of general intelligence need to be taken in account. For instance, Watkins et al. (2005) contended that despite the fact that subtest assessment and interpretation are common practice in research, it has methodological, statistical and psychometrical difficulties especially in clinical purposes.

Further, Matthews et al. (2000) pointed out a critical issue. They argued that specific abilities subtests have shown surprising similarity with general intelligence tests and that general intelligence tests are better for long-term prediction because people compensate abilities with strategies. These issues would indicate a reduction of validity of specific ability assessment data to compare visual and verbal information processing efficiency. Another potential influence factor for visual information design researcher is the qualification requisites to administer norm-based tests that require direction of a trained psychologist. At this point, ETS kit seems to be the more accessible test for the design field. Finally, for design research, it is recommended to review the complete tests beyond the suggestions of this section because other subtests might be useful for special conditions of visual information design.

For MI theory, as it was said above, there is not a norm-referenced test because the theory rejects the use of psychometric tools. The use of formal MI assessment is only possible with qualitative techniques and a thorough observation process. This explains why a deep study of assessment with MI theory can be found only in education, where instruction and assessment can occur in a regular feedback (Chen and Gardner, 2005). In spite of this absence of practical tools in other applications outside education, the basic rules can be extrapolated for other types of research. That eventual research should model a context to find out the intelligence profile of the participant, specifically linguistic and visuo-spatial intelligences for the case of visual information research. At least four elements would be needed to create the MI "ecological validity" (ibid): measure each intelligence in its own code (spoken and written language for linguistic intelligence and picturing/mapping for visuo-spatial intelligence), measure each intelligence vertically without correlating other capacities like speed processing between intelligences, use known elements to avoid cognitive difficulties of content or knowledge, and ensure motivation of the participants to achieve the tasks.

This scheme would need a middle-long term measurement and the establishment of performance assessment criteria, which implies significant efforts in time and budget to obtain reliable data. Previous research has attempted different procedures from those suggested by Chen and Gardner (ibid). For instance, Martin (2003) explored the use of this theory using self-report techniques with a "multiple intelligence personal preference inventory" to do an experimental research study. He studied the intelligence profiles and professional preferences in business students but his methods are difficult to validate because of the inaccuracy of the self-estimated data. Another possibility to use MI theory would be test people with specific source context using the assertion that MI profiles are developed according to context and individual decisions. From this basis one can argue that law or business professionals would have a strong linguistic ability because they have taken individual decisions and participated in special contexts to learn and improve skills in a domain that requires demanding verbal tasks. As well design and engineer professionals would have developed visuo-spatial abilities likely of their daily demands with spatial problem solving.

4. Applicability in Visual Information Design Research

The question that this paper explores is whether intelligence measurement tools that measure verbal and visual intelligence can be used in a user-centered design approach in such a way that the identification of strengths and weaknesses in visual information design quality and performance can be measured. Otherwise, these intelligence measurement tools will remain psychological measures rather than tools for design. For example, intelligence assessment measures might be used to identify how information performs with low and high ability individuals and therefore what design principles may make greatest improvements in the overall design quality for all subjects. It is assumed that besides adapting the tool to the intention of the study, it will be necessary to redirect the focus of the subjects on information processing or information creation. For example, it is not the same the range of spatial abilities needed to design a building or to walk through it. Furthermore, different visual information interactions and settings might change drastically the sort of abilities needed. For example, visual information of a wayfinding system demands different abilities compared with a web site interface.

Consequently, use of intelligence measurement tools should only be done after careful research design to fit specific circumstances and hence, to obtain meaningful data. Intelligence assessment tools selection depend upon various methodological approaches of quantitative, qualitative or mixed data collection. Undoubtedly, a quantitative research design is compatible with psychometric assessment using the foundations of CHC theory. A qualitative research design is compatible with the tools suggested in the MI theory. The RIAS test seems to be the more consistent scale of measurement with CHC theory because it focuses on the two significant areas of visual information: verbal and visual ability. Also it determines a level of general intelligence, which avoids subtest problems mentioned about reliability and validity. However, ETS kit factor-referenced cognitive test is useful for its accessibility, flexibility, and acceptance in the scientific community. CHC theory tools also might facilitate future factor analysis with near fields like information visualization or human-computer interaction that already started to use this theory for research. Behind the MI theory there is no existent tool to use, but design research might apply its principles. The advantage of this theory for design research resides in the observation of people's adaptation process and interaction with real context analysis, which is strongly recommended in user-centered design theories (See Norman, 1983; Cooper et al., 2007).

One of the difficulties of CHC theory is the use of abstract content, which opposes the visual information design performance of real environments and perhaps obtains contradictory results. For example someone that is measured with low visual ability might use easily visual icons if those icons are strong conventions in his or her culture. In this case assessment suggested by MI theory can be useful because the use of the visual information could inform the researcher about intellectual abilities. The arguments of fair assessment contended by MI theory to create "ecological validity" are greatly consistent, however they contravene practical issues always preferred in research. The possibility to use profiles from specific source context like professional areas is promising because it resolves the practical requirements. But these are pending to studies to determine reliability, validity, and limitations of the method.

Self-estimates of intelligence could be useful in exploratory studies, although there is not clear consensus in how accurate they are. Ackerman and Wolman (2007), observe that self-concept, self-efficacy and self-esteem may affect self-estimates of intelligence. Hence, with self-estimates would be essential the inclusion of other psychological cause of variation like personality, experience, or expectations. These sorts of complexities bring to the table the correspondent concepts above described of *adaptation* of Chen and Gardner (2005) and *compensation* of Matthews et al. (2000). They become relevant because use of visual information design in real world is time based. Reuse is certainly more present than first use of design object. So, visual information design performance cannot be only based on first time use but also on how the performance varies according as users adapt using their ability strengths and compensating their weaknesses.

5. Conclusions

For all the reasons explained above there is currently no easy way for the design researcher to include either CHC or MI intelligence theory in visual information design research. Even though this analysis provides an initial guide for design research methods for projects involving human abilities, there are no definitive reliable tests available to guide designers in assessing user's level of inherent visual intelligence. Currently, designers lack the ability to predictively measure user's verbal and visual reasoning capacities and its effect on communication quality of design objects. Current assessment suggests a combination of qualitative and quantitative tests to compare verbal to visual intelligence, which should be designed according to correspondent particular aims. This may provide some guidance, but to date, explicit workable measures do not exist. This combination of data would improve strengths and reduce weaknesses of quantitative and qualitative approaches. It can provide an insightful knowledge of the phenomena (Creswell & Plano, 2007), but it is essential to control carefully the scope of the research to achieve goals for either studies embedding mixed quantitative and qualitative data or continuous projects that involve initial exploratory qualitative inquiries and a later quantitative defined stage. In these cases exploratory and qualitative studies are more compatible with MI theory and objectivist quantitative studies with CHC theory.

Whichever case, design researchers should avoid directly adapting intellectual ability measures disconnected from the design object attributes. The central outcome should be to identify and test visual information design features that affect the quality and performance to provide principles for efficient communication and interaction. Such eventual data would inform the design process about individual differences in order to make design more universal. This would empower design practitioners to create visual information that is readable and usable for people with different levels and profiles of verbal and visual ability. As well, further studies in intelligence assessment for visual information design might include specific issues like assessment instruments; the difference between proficiency and aptitude; how visual information can contain learning aids that affect the aptitude and increase communication efficiency; and how the youth generation, that are apparently more visual literacy competent, will modify expected traditional behaviors and interactions with visual information.

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