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The Use of Infographics to Assess Context Processing

Beliz Hazan

The Graduate Center, City University of New York

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THE USE OF INFOGRAPHICS TO ASSESS CONTEXT PROCESSING

by

BELIZ HAZAN

A dissertation submitted to the Graduate Faculty in Psychology partial fulfillment of the requirements for the degree of Doctor of Philosophy, The City University of New York

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The Use of Infographics to Assess Context Processing

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This manuscript has been read and accepted for the Graduate Faculty in Psychology in satisfaction of the dissertation requirement for the degree of Doctor of Philosophy.

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Abstract

The Use of Infographics to Assess Context Processing

by

Beliz Hazan

Advisor: Daniel D. Kurylo

Among high-order cognitive functions is the use of context to enhance comprehension of language or visual scenes. Although use of context is known to be impaired in certain clinical populations (e.g., schizophrenia), no existing test adequately assesses this construct. To fill this gap, we developed and attempted to validate a test of context use that employed Infographics (information graphics), which requires the use of context to interpret visual displays. The primary hypothesis was that interpreting Infographics would be sensitive to context processing. We further hypothesized that different levels of cognitive processing (requiring basic perceptual, real-world application, or verbal reasoning), as well as different categories of Infographics (Data Display, Maps, Diagrams, or Timelines) would tap differential cognitive functions. Forty Infographics test items were developed based upon design principles of Infographics. Following development of items, the Infographics test, as well as a battery of neuropsychological tests, were administered to 161 participants. Overall, results revealed that our Infographics did target context. However, the test also places significant demands on verbal reasoning and similar cognitive functions apply to each level of cognitive processing. Finally, results indicated that similar cognitive functions applied to all categories of Infographics, with the exception of the three of the categories of Data Display, Maps, and Diagrams, which were associated with
graphical literacy skills, whereas Timeline was not. In sum, we present data that a newly developed Infographics test is a valuable tool to assess context, and may be applied to evaluate individual differences among healthy individuals, as well as to evaluate impairment in patients with specific clinical diagnoses. However, test performance is not specific to context processing and the test is also sensitive to other high-order cognitive functions, including verbal reasoning.
Acknowledgments

Throughout my school life, among my other projects, this dissertation serves as a symbol of creativity, perseverance, and numerous times of considering giving up. Instead, taking breaks and working harder brought me to this point. This entire project by itself not only taught me to focus on the conclusions, but also encouraged me to gain a deep understanding of the process. First of all, I would like to thank my advisor Daniel Kurylo who initiated this deep and wise process. He was patient with my endless questions, always listened to me carefully and provided logical and intellectual advice. He encouraged me to complete each stage with perseverance. I was lucky to have such a creative, patient, and open-minded scientist as my advisor. During the brainstorming sessions, he shared his ideas regarding how to bridge art and science, how to solve problems in a creative way along with critical thinking, and how to think globally without skipping any details. Every single word from him was essential and opened a new window for me in each phase of the dissertation. I will always remember his teachings with a big smile and apply them to my daily life. I also would like to thank Laura Rabin for her insightful and wise contributions to this dissertation. Her tireless editing and questions containing critical thinking enabled me to examine this dissertation from different perspectives. Additionally, her generosity to share her sources (e.g., books, neuropsychological tests) facilitated the administration process. Without these sources, I could not implement the study. I would like to thank Elisabeth Brauner, Robert Duncan, and Aaron Kozbelt for their constructive comments for this dissertation. I also remember and would like to thank David Owen for guiding me in statistics at the beginning of this dissertation. I would like to thank my research assistants for assisting me in scoring the neuropsychological tests and entering each data point into the computer. Without their help, it would not be possible to develop a reliable test.
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# Table of Contents

Table of Contents........................................................................................................................................ii

List of Figures....................................................................................................................................................ix

List of Tables.................................................................................................................................................... xi

Chapter 1: Introduction.................................................................................................................................... 1

Chapter 2: Methods......................................................................................................................................... 21

Chapter 3: Results............................................................................................................................................ 37

Chapter 4: Discussion..................................................................................................................................... 61

Figures............................................................................................................................................................ 82

Tables............................................................................................................................................................. 106

Appendix A.................................................................................................................................................. 117

Appendix B.................................................................................................................................................. 123

References..................................................................................................................................................... 130
List of Figures

Figure 1. An example of Infographics ................................................................. 82
Figure 2a. An example of Level 1 test items ...................................................... 83
Figure 2b. An example of Level 1 test items ...................................................... 84
Figure 2c. An example of Level 1 test items ...................................................... 85
Figure 3a. An example of Level 2 test items ...................................................... 86
Figure 3b. An example of Level 2 test items ...................................................... 87
Figure 3c. An example of Level 2 test items ...................................................... 88
Figure 4a. An example of Level 3 test items ...................................................... 89
Figure 4b. An example of Level 3 test items ...................................................... 90
Figure 4c. An example of Level 3 test items ...................................................... 91
Figure 5a. An example of levels of difficulty for Level 1 Infographics ................. 92
Figure 5b. An example of levels of difficulty for Level 2 Infographics ................. 93
Figure 5c. An example of levels of difficulty for Level 3 Infographics ................. 94
Figure 6a. Histogram of Level 1 Item 4 Distribution ........................................ 95
Figure 6b. Histogram of Level 1 Item 9 Distribution ........................................ 96
Figure 6c. Histogram of Level 1 Item 11 Distribution ....................................... 97
Figure 7. Histogram of Distribution of Infographics ........................................ 98
Figure 8a. Histogram of Level 1 Infographics Distribution ................................ 99
Figure 8b. Histogram of Level 2 Infographics Distribution ................................100
Figure 8c. Histogram of Level 3 Infographics Distribution ................................101
Figure 9a. Histogram of Data Display Distribution .........................................102
Figure 9b. Histogram of Diagram Distribution .................................................103
Figure 9c. Histogram of Map Distribution .............................................104

Figure 9d. Histogram of Timeline Distribution.............................................105
List of Tables

Table 1. Summary Table of Level of Cognitive Processing and Category of Infographics for Each Item………………………………………………………………………………………………………………………………………………106

Table 2. Neuropsychological Tests ……………………………………………………………………………………………………………………………………………………………………………………………………………107

Table 3. Reasons for the Data Exclusion …………………………………………………………………………………………………………………………………………………………………………………………108

Table 4. Data Transformation Formulae……………………………………………………………………………………………………………………………………………………………………………109

Table 5. Descriptive Statistics For Each Test Item………………………………………………………………………………………………………………………………………………………………110

Table 6. Descriptive Statistics and Normality Test for Each Neuropsychological Test…………………………………………………………………………………………………………………112

Table 7. Descriptive Statistics for Average Scores (Z Scores of Transformed Average Scores)…………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………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Chapter 1: Introduction

Context Processing

Context can be defined as “the part of language that precedes or follows a word or text and clarifies its meaning” (Murray, Bradley, Craigie, & Onions, 1933; as cited in Hemsley, 2005b, p. 44). Unlike a unified definition of context, different definitions prevail by means of tasks that are utilized to measure the related cognitive functions (Braver, Rush, Satpue, Racine, & Barch, 2005; Cohen & Servan-Schreiber, 1992; Cohen, Barch, Carter, & Servan-Schreiber, 1999; Hemsley, 2005a; Hemsley, 2005b; Park, Lee, Folley, & Kim, 2003). Park et al. (2003) distinguished the identification of perceptual context and cognitive context. Perceptual context can be defined in different ways depending on task requirements. For instance, if the task consists of several visual characteristics (e.g., color, size, shape), and requires to focus on one of them, the other characteristics may serve as context. On the other hand, if the task requires to focus on overall visual characteristics, the background may serve as context as seen in perceptual organization tasks (Kurylo, Pasternak, Silipo, Javitt, & Butler, 2007; Silverstein & Keane, 2011).

Cognitive context corresponds to the relationship between long-term memory and visual perception (Hemsley, 2005a; Park et al., 2003), and can be associated with either inhibition or working memory depending on the task (Cohen & Servan-Schreiber, 1992). Understanding cognitive context might require to keep the task instructions in mind in working memory tests, and inhibit habitual features that are not related to the task requirements in attention tests (Cohen & Servan-Schreiber, 1992; Cohen et al., 1999; Park et al., 2003). Phillips and Singer (1997), and Phillips and Silverstein (2003) described context processing not only occurred in working memory, but also can be generalized to all levels of information processing from low level perceptual processes to higher level cognitive functions. As mentioned above, operational
definitions of context are crucial to understanding the underlying cognitive functions. Based on a
generalized application of context processing, in this study context is operationally defined as
global information processing through comparison across the images.

A Need of Context Processing Assessment

Context processing may be impaired in clinical populations such as patients with
schizophrenia (Braver et al., 2005; Hemsley, 2005a; Hemsley, 2005b; Phillips & Singer, 1997;
Phillips & Silverstein, 2003). For instance, a subjective complaint of a patient can be seen as
follows “Only saw fragments: a few people, a kiosk, a house. To be quite correct, I cannot say
that I see all of that, because the objects seemed altered from the usual. They did not stand
together in an overall context, and I saw them as meaningless details” (Matussek, 1987; as cited
in Silverstein & Keane, 2011, p. 690). This complaint might have occurred as a result of a
perceptual organization (PO) deficit that did not enable the patient to integrate and organize local
features to perceive the scene as a whole entity (Silverstein & Keane, 2011). In addition to the
visual aspect, impaired context processing might have contributed to PO deficit (Phillips &
Silverstein, 2003; Phillips & Singer, 1997; Silverstein & Keane, 2011). Context serves as a key
factor for cognitive coordination that is a mechanism that initiates grouping at a neuronal level as
well as plays a crucial role in higher cognitive functions (Phillips & Silverstein, 2003; Phillips &
Singer, 1997). The need for global processing in accordance with PO has been examined by
using a number of perceptual and cognitive tasks such as Navon task (Navon, 1977) or
configural tasks (for a review see De-Wit & Wageman, 2015). However, in these tasks, the role
of context processing has not been specified. In the previous studies, global processing was
examined at a perceptual level to recognize a low spatial frequency image (Ben-Yosef, Anaki, &
Golan, 2017) or to combine visual features to make an entity (e.g., lines to make a square) (De-
Wit & Wageman, 2015). Global processing facilitates transformation of integrated visual features into a whole entity such as a scene through interpretation of contextual information at a cognitive level (Ben-Yosef et al., 2017; Torralba, Oliva, Castelhano, & Henderson, 2006).

Previous studies investigated context processing using perceptual tasks (Uhlhaas, Phillips, Mitchell, & Silverstein, 2006; Yang et al., 2013; for a review see Silverstein & Keane, 2011). Specifically, visual context processing has been investigated in patients with schizophrenia across different aspects of perceptual context such as luminance, contrast, size (Yang et al., 2013) through utilizing illusion tasks such as Ebbinghaus size illusion that consisted of a centered circle along with the surrounding circles (Uhlhaas et al., 2006; Silverstein & Keane, 2011; Yang et al., 2013). Context processing deficit was also examined through utilizing modified neuropsychological tests such as AX-Continuous Performance Test (AX-CPT; Barch, Carter, MacDonald, Braver, & Cohen, 2003; Braver et al., 2005; Cohen & Servan-Schreiber, 1992; Cohen et al., 1999; Servan-Schreiber, Cohen, & Steingard, 1996), and Stroop Test (Stroop, 1938; Cohen & Servan-Schreiber, 1992; Cohen et al., 1999). For instance, Servan-Schreiber and colleagues modified the Continuous Performance test by changing the delay between a target (X) and a cue (A) that represents the context, and generated AX-CPT that required the participants to suppress non-contextual cue (Servan-Schreiber et al., 1996). Their results supported their argument that patients may have difficulty in inhibition due to context processing deficit. Context processing deficit was also investigated in language processing through the use of Lexical Disambiguation Test (Cohen & Servan-Schreiber, 1992; Cohen et al., 1999) and Hayling Sentence Completion Task (Burgess & Shallice, 1997; Wykes & Reeder, 2005). However, in these tests the role of global processing has not been identified.
In sum, context might be a part of language processing (Burgess & Shallica; 1997; Cohen & Schreiber, 1992; Cohen et al., 1999; Hemsley, 2005b; Wykes & Reeder, 2005), visual processing (Uhlhaas et al., 2006; Silverstein & Keane, 2011; Yang et al., 2013), working memory (Cohen & Servan-Schreiber, 1992; Servan-Schreiber et al. 1996), or might be more generalized (Phillips & Silverstein, 2003). To date various objective tasks (for a review see Silverstein & Keane, 2011) and various (original or modified) standardized neuropsychological tests (Barch et al., 2003, Cohen & Servan-Schreiber, 1992; Cohen et al., 1999; Servan-Schreiber et al., 1996) have been used to assess context processing and pinpoint related cognitive functions. However, to our knowledge, global processing tasks that are related to perceptual organization (e.g., Navon task) did not identify the role of context. Similarly, the standardized neuropsychological tests which were used to measure context processing did not define the role of global processing. Although these tests tap into different cognitive aspects, no standardized test has been developed to assess context processing as a global processing through comparison of visual images. To fill this gap, in this study, Infographics (information graphics), which requires the use of context, was considered as a tool to assess context processing.

**Role of Context in Interpreting Infographics**

**Visualization**

Visualization literacy incorporates skills to comprehend data by means of visual patterns on the visual representations (e.g., line graphs, bar graphs) (Börner, Bueckle, & Ginda, 2019; Boy, Rensink, Bertini, & Ferkete, 2014; Chen & Floridi, 2013). Visualization plays a crucial role in disseminating information quickly, accurately and effectively in different settings (e.g., education, journalism, research) (Islamoglu et al., 2015; Nesbit & Adesope, 2006). Visual
representations are utilized for communication (Tversky, 2011) and finding solutions for the problems (McCormick, DeFanti, & Brown, 1987; Tufte, 1983).

Throughout history, visual representations have assisted in the comprehension of data (e.g., bar charts and pie charts invented by William Playfair, one of the pioneers of graphical methods of the statistics) (Friendly, 2002; Tufte, 1983) and information (e.g., medical illustrations drawn by Fritz Kahn, physician, one of the pioneers of infographics) (Popova, 2013; Von Debschitz & Von Debschitz, 2017) across settings and contexts (i.e., politics, education, journalism) (for a review see Friendly, 2002, 2008; Hegarty, 2011; Tufte, 1983). For instance, Charles Joseph Minard, an engineer known for his graphical drawings, facilitated comprehension of Napoleon’s losses during the French invasion of Russia through drawing a flow map (Friendly, 2002; Tufte, 1983). Otto Neurath, a philosopher of science, proposed a picture language called the International System of Typographic Picture Education (ISOTYPE) to facilitate statistics comprehension in the context of education of history, technology and other educational settings by means of visual display of repetitive icons called “pictograms” (for a review see Burgio & Moretti, 2017; Burke, 2009; Burke, Kindel, & Walker, 2013). Although the purpose of the pioneers of visualization has been to make information clear and understandable, not all of these pioneers have conveyed the same point of view in terms of the structure of visual displays. For instance, Holmes (1984) as a journalist illustrated bar graphs and line charts by adding graphical elements that do not represent data to facilitate readers’ understanding of graphs from newspapers. Unlike Holmes, Tufte (1983), one of the pioneers of information visualization, indicated the importance of simplifying visual displays by avoiding these graphical elements (Gough, Ho, Dunn, & Bednarz, 2014). Empirical studies (e.g., Bateman, 2010) and scholarly well-known sources (e.g., Cairo, 2013) examined both Tufte’s minimalistic approach
and Holmes’ illustrative approach and explained the importance of both in terms of perceptual and memory performance.

Visual representations can occur as visual-spatial displays (Hegarty, 2011), information visualization (Ware, 2012), infographics (Islamoglu et al., 2015; Smiciklas, 2012), data visualization (Friendly, 2008), and abstract graphics (Malamed, 2009; Tversky, 2011). Definitions of data and information can be important to understand the aforementioned visual representations. Data are facts without meaning, such as numbers (Rowley, 2007). Once meaning is attributed to data, data become information as seen in equations (Rowley, 2007).

Infographics, which stands for informational graphics, can be described as a combination of text, visual pictures, and graphs to demonstrate data and information through visual storytelling (Islamoglu et al., 2015; Smiciklas, 2012). Infographics enable observers to focus on holistic characteristics of the image, referred to as Gestalt thinking (Islamoglu et al., 2015). Even though infographics are mostly used as another form of data visualization, several characteristics distinguish infographics from purely displayed data. For example, infographics tell a story through using the combination of visual images, graphs, and text (Islamoglu et al., 2015; Krum, 2013) and can be created by hand in a design software (Steele & Ilinsky, 2010); data visualization, by contrast, follows specific computer-based formulae and are typically more data oriented than infographics (Steele & Ilinsky, 2010).

Each visualization format may have its own classifications (Lohse, Biolsi, Walker, & Ruelter, 1994), or categories (Malamed, 2009) depending on its structure versus function (Lohse et al., 1994), or relationships among the entities (Hegarty, 2011; Malamed, 2009). For instance, the relational display as a type of visual-spatial display demonstrates connection between the information (e.g., real-world objects) and representing basic geometrical shapes along with
visual variables (e.g., point, line, area along with shapes, size, length, color) (Hegarty, 2011). The relational displays are portrayed as abstract graphics (Malamed, 2009).

The terms “graph”, “diagrams”, or “charts” have varying definitions in the literature (Börner et al., 2019; Kosslyn, 1994; Ratwani, Trafton, & Boehm-Davis, 2008; Shah, Freedman, & Vekiri, 2005; Ware, 2012). For instance, in some sources a flowchart is categorized as a chart (e.g., Kosslyn, 1994), while in other sources they were accepted as a diagram (e.g., Ware, 2012). Graphs are accepted as visual representations that are used to reflect the quantities in the real-world applications by means of visual features (Bertin, 1983; Pinker 1990; for a review see Shah et al., 2005). Although the word “graph” is a general term used to describe types of data displays such as “bar graphs”, or “line graphs” (Pinker, 1990), previous studies incorporated maps (Ratwani et al., 2008) to examine the process of understanding graphs (Ratwani et al., 2008). Due to mixed definitions, in this study, four types of abstract graphics (data display, diagrams, maps, timeline) explained by Malamed (2009) were used to generate the test items.

**Data display.** Data display incorporates relationships among quantitative information and seen as bar charts (displaying the changes across the discrete values), pie charts (displaying proportions of a whole), line charts (displaying the changes across the continuous variables) (Kosslyn, 1994; Malamed, 2009; Pinker, 1990), and pictographs (displaying number of icons to represent quantitative information) (Burke, 2009; Burke et al., 2013; Malamed, 2009).

**Diagrams.** Diagrams incorporate entities to connect qualitative information (Malamed, 2009) that are more descriptive compared to data displays. Diagram are used for displaying not only structures or functions of a system (e.g., how a phone is structured or how a car works) (Malamed, 2009) but also associations among nodes (i.e., entities) through links (i.e., connections among entities) as emphasized by Ware (2012). Node-link diagrams can be
constructed as flowcharts, hierarchical diagrams, network diagrams, process diagrams (Munzner, 2015; Tversky, 2011; Ware, 2012).

**Maps.** Maps demonstrate spatial associations among locations that can be seen in subway maps, or world maps (Kosslyn, 1994; Malamed, 2009; Tversky, 2005, 2011). Thematic maps, a type of maps, display quantitative information along with locations (Bertin, 1983; Lohse et al., 1994). Thematic maps can be seen as choropleths (displaying quantitative data by means of different colors and shades), dot maps (displaying quantitative data by changing the quantity of dots in relation to the corresponding region), cartograms (displaying quantitative information by means of changing the size of regions) (Krygier & Wood, 2016), flow maps (displaying changes in action from one place to another-e.g., immigrations from one place to another) (Boyandin, Bertini, & Lalanne, 2010).

**Timelines.** Timelines display sequential changes over time (i.e., years, days, or the past, present and future) (Malamed, 2009; Tversky, 2011). Timelines may demonstrate growth (i.e., development stages), changes in events over the time seen in historical timelines or changes in tasks in projects as seen in Gant charts (Malamed, 2009).

**Perceptual and Cognitive Functions Related to Interpreting Abstract Graphics**

In order to examine perceptual and cognitive functions related to extracting information from the abstract graphics, visual-spatial representation based properties (e.g., visual variables, difficulty of data, or task requirements) as well as viewer based properties (e.g., working memory, knowledge on how to read a graph, or familiarity with the content) have been examined through the administration of the tasks (Shah et al., 2005). Shah and colleagues (2005) reviewed the tasks in terms of tapping into perceptual and cognitive processes. The first group of tasks examine perceptual processes such as comparing two values of visual variables (e.g., Simkin &
Hastie, 1987). The second group of tasks require more complex processing to examine the contribution of knowledge on how to read a graph accurately in addition to perceptual processes (e.g., Pinker, 1990).

Theories behind identifying information contained in graphs vary depending on whether the process contains *specific information extraction* or *integrative information extraction* (Ratwani et al., 2008). *Specific information extraction* requires information processing steps that are initiated by coding visual characteristics of a visual display, defining the corresponding quantitative features, and making an association in correspondence to the real-world meaning (Bertin, 1983; Brouwer, 2014; Ratwani et al., 2008; Shah et al., 2005). *Integrative information* incorporates two stages (visual integration and cognitive integration) into information processing held in *specific extraction* (Ratwani et al., 2008). Visual integration is initiated with the combination of visual variables depending on mutual features that they share (e.g., size), or semantic categories to which they belong. This process leads to visual pattern processing. Cognitive integration indicates how comparing grouped features makes a meaningful unit (Ratwani et al., 2008). Spatial aspect (Ratwani et al., 2008) and Spatial Contiguity Theory, which refers to the closeness of words and related graphics (Islamoglu et al. 2015; Mayer, 2005), may assist in integrating information processing. The meaning of spatial associations may vary depending on the type of abstract graphics. For instance, spatial association demonstrates the time difference in a timeline (a figurative difference), or differences between two distances on a map (a real-world location-based difference) (Malamed, 2009; Tversky, 2005, 2011).

**Design Principles**

Abstract graphics represent concrete information (Malamed, 2009). Design principles help ensure that the abstract visual features represent accurate, and meaningful information
(Tufte, 1983) and the visual representations are compatible with perceptual and cognitive processes (Kosslyn, 1994).

**Factors Contributing to Design Principles**

Design principles can be explained by good and bad examples (Tufte, 1983, 1990, 2006), the building blocks of information visualization (Bertin, 1983; Hegarty, 2011; Munzner, 2015), empirical studies (Cleveland & McGill, 1984; Garlandini & Fabrikant, 2009; Hegarty, 2011; Tversky, 2011). For the current study, we took design principles into account during development of the infographics test items.

**Good and bad examples.** Tufte (1983, 1990) proposed prominent design principles by examining good and bad examples of transforming data into simple, clear, and meaningful graphs. According to Tufte's principles, a good graphical display should enable readers to compare data through visual features, such as color or thickness, and provide a better understanding of the meaning of graphs by demonstrating causality between the parts, as well as integrating words, texts and graphs together (Tufte, 1983, 1990). In addition, a good visual display should demonstrate data accurately, be compatible with statistical and verbal explanations, and simplify a large data set. A good graphical display should not include a “lie factor” (tendency to deviate factual data in a graph), “redundant ink” (ink which was devoted to non-utilized information), and “chart junk” (overestimation of graphical effects) (Tufte, 1983). Tufte (1983) crucially examined the previous graphics in history. According to Tufte (1983), the graph that displayed Napoleon’s losses during the French invasion drawn by Charles Joseph Minard was accepted as a good graph as it reflected these principles. On the other hand, the graph that was presented to the engineers in the Challenger, a space shuttle that exploded, was
accepted as a bad example as it did not contain these basic principles (Shah et al., 2005; Tufte, 1983).

**Building blocks of information visualization.** Building blocks of information visualization are tools made up of basic geometric shapes and visual variables to display the information on a visual setting (Bertin, 1983; Cleveland & MacGill, 1984, 1985; Garlandini & Fabrikant, 2009; Munzner, 2015). Bertin (1983) proposed *marks* as basic geometric shapes such as point, line, and areas and visual variables *as visual attributes* such as color, length, shape. The visual variables were ranked from the most to least effective (Bertin, 1983; Garlandini & Fabrikant, 2009; Munzner, 2015).

**Empirical studies.** Cleveland and McGill (1984) conducted research to examine visual displays via visual perception to determine the most accurate to least accurate judgments. Results were displayed in the following order: “*The position common scale, the position non-aligned scale, along, length, direction and angle, area, volume, curvature, shading and color saturation*”. Different empirical studies compared different visual displays such as line graphs and bar graphs (e.g., Shah & Freedman, 2011), or bar charts and pie charts (e.g., Simkin & Hastie, 1987), maps (e.g., Garlandini & Fabrikant, 2009) to identify the most accurate visual representation corresponding to the information they represent.

**Classification of Design Principles**

Taking into account these factors, in the literature there are several classifications of design principles (Hegarty, 2011; Kosslyn, 1994; Munzner, 2015). For the current study, design principles were examined in terms of expressiveness and effectiveness emphasized by Munzner (2015) and other relevant principles were incorporated accordingly (Hegarty, 2011; Kosslyn,
During the development of the infographics test items, this classification was taken into account.

Expressiveness indicates congruency of the visual variables with features of corresponding data they represent (Hegarty, 2011; Kosslyn, 1994; Munzner, 2015). Kosslyn (1994) explained this principle through a statement of “the mind judges a book by its cover” indicating that each data point should be represented by its corresponding marks and visual variables. For instance, if the data represent young people eating more ice cream than old people on a bar graph, the bar that represents young people should be longer than the one that represents old people. Based upon Bertin (1983) and Cleveland and McGill (1984), Munzer (2015) proposed two types of visual variables depending on the ordered and quantitative information (e.g., depth, color luminance, color saturation), and categorical information (e.g., color hue, shapes).

Effectiveness refers to the success in detecting changes between two values of visual variables (Munzer, 2015). Munzner (2015) utilized the term values to point out the changes across visual variables (e.g., different values of a color). The principle of effectiveness was determined based upon a crucial examination of visual displays on accuracy, discriminability, separability, pre-attentive features and perceptual grouping (Munzner, 2015) and visual salience (Hegarty, 2011). Each factor is accepted as a separate principle in other sources (Hegarty, 2011; Kosslyn, 1994). Accuracy determined by psychophysical measurements (Munzner, 2015) and empirical studies (Cleveland & McGill, 1984) indicates how much discrepancy exists between the physical properties of a stimulus and the human perception on the same stimulus (Munzner, 2015). Discriminability describes how different values of a visual variable should be differentiated based upon the noticeable changes across the values (Hegarty, 2011; Kosslyn,
For instance, two different values of thickness of lines can be discriminable from each other (Kosslyn, 1994; Munzner, 2015). Separability indicates how two visual variables (e.g., color-shape) or two different values of one visual variable (e.g., two color) can be separated from each other (Munzner, 2015; Ware, 2012). Not all visual variables are separated evenly. Two visual variables such as color and shape can be perceived as one entity, meaning that these variables are more integrative (Kosslyn, 1994; Munzner, 2015; Ware, 2012). However, other two visual variables such as location and color can be perceived as separate entities (Munzner, 2015; Ware, 2012). Pre-attentive features proposed by Triesman (1985) can be utilized for differentiating background from figure or different colors embedded into pictograms on a map (Cairo, 2013). The use of Gestalt principles such as proximity and good continuation play a crucial role in determining effectiveness (Munzner, 2015; Pinker, 1990; Tversky, 2011). Visual salience is influenced by discriminability of different values of a visual variable (Munzner, 2015), pre-attentive processing (Triesman, 1985), and perceptual grouping—which together demonstrate how values of a visual variable vary in the most noticeable way (Bertin, 1983; Cairo, 2013; Hegarty, 2011; Kosslyn, 1994; see for a review Munzner, 2015).

**Comparison Through Relative Values**

Comparing two different values of visual variables and/or differentiating one value from another (e.g., comparing two different sizes of a line) (Kosslyn, 1994) is based upon relative values between two entities rather than absolute values (Gescheider, 2013; Munzner, 2015). Weber’s Law emphasized that the detectable difference between variables can be identified based upon the changes in intensity of the target variable (Gescheider, 2013; Munzner, 2015). This process requires at least two values of the same visual variable: one target entity and another similar entity as a reference point to differentiate one from another. The role of pre-
attentive features (Cairo, 2013; Malamed, 2009; Munzner, 2015; Triesman, 1985) may serve as a facilitator for comparison (Cairo, 2013; Kosslyn, 1994).

**The Role of Context in Interpreting Abstract Graphics**

Context is necessary to comprehend graphs, visual images, and various iconic images. For instance, at a perceptual level, color perception and luminance are influenced by the background color (Ware, 2012; Munzner, 2015). At a cognitive level, graphical elements such as arrows used in diagrams (Malamed, 2009; Tversky, 2011) or pictograms are context-dependent (Tijus, Barcenilla, Lavalette, & Meunier, 2007). Good visual-spatial displays include comparison of data through visual variables (e.g., color, length) to provide context by asking “compared to what” (Tufte, 1983). For instance, Tufte (1983) emphasized the importance of context in understanding graphics through examining a series of line graphs (Campbell & Ross, 1970) that explains the effect of strict regulations on elimination of speeding in Connecticut. In the first graph, due to insufficient time points and number of states, context was not clear. In the second graph, although adding different time points enabled viewers to compare the existing situation to the previous time slots, still the graph did not answer the question in terms of the comparison across the states. The last graph emphasized the big picture by clarifying the context through adding other states as well as multiple time points. Therefore, comparison is crucial to understand the context of a graph (Tufte, 1983). A good graph can also be holistically perceived through Gestalt thinking that indicates global information processing (Islamoglu et al., 2015).

Taken together, research and theories on cognitive functions associated with Infographics highlight processes related to integration, either with integrating graphics, figures, and text, or integrating information. Cognitive processes facilitate extracting information from holistic, or Gestalt, relationships that are contained in the image. Comparison of variables (Munzner, 2015;
Tufte, 1983) and global information processing (Islamoglu et al., 2015) are crucial to understand context.

**Summary of the Literature Review**

Patients with schizophrenia may have perceptual organization deficits that lead to dysfunctions in context processing (Hemsley, 2005a; Hemsley, 2005b; Phillips & Singer, 1997; Phillips & Silverstein, 2003). Although different neuropsychological tests have been used to evaluate context processing (e.g., Cohen & Servan-Schreiber, 1992), to date no standardized test has been developed to evaluate context processing as global processing through comparison. Proper designed infographics include comparison of data through visual images (Kosslyn, 1994; Munzner, 2015; Tufte, 1983), which can be holistically perceived through Gestalt thinking (Islamoglu et al., 2015). Context is thereby necessary to comprehend infographics through comparison and global processing. Cognitive functions associated with complex graphs highlight processes related to integration of visual variables. Based upon the integrative characteristics of infographics, as well as the necessity to extract holistic information, infographics are ideally suited to develop a standardized test of context processing.

Information processing during interpretation of graphs include comparing visual variables, identifying associations with quantitative features, and making a connection with the real-world meaning (Bertin, 1983; Pinker, 1990; Ratwani et al., 2008; Shah et al., 2005). Visual and cognitive processes can be incorporated into these processes in integrative extraction theory (Ratwani et al., 2008). Visual representation based properties (e.g., visual variables) and viewer based properties (e.g., knowledge on how to read a graph) (Pinker, 1990) may contribute to these processes (Shah et al., 2005). Information processing stages may be related to different cognitive functions.
Previous studies utilized various abstract graphics (e.g., maps, data display, diagrams, timelines) (Cleveland & McGill, 1984; Lohse et al., 1994; Ratwani et al., 2008; Shah et al., 2005), to explore cognitive and perceptual processes underlying the graphics (for a review see Shah et al., 2005). Each abstract graphic may be related to different cognitive functions.

**Overview of the Current Study**

In the current study, a standardized test of context processing test will be developed through the use of infographic displays. Specifically, 40 test items will include four types of abstract graphics (*data display, diagrams, maps* and *timeline*), each presented at three levels of cognitive processing: *Low-level* (infographics are based entirely upon visual variables), *mid-level* (visual variables are relating to real-world applications), and *high-level* (visual variables are related to real-world applications, whereas additional information contained within the display is based upon categorization of these variables). Participant performance will be based upon procedures adapted from visual psychophysics. Specifically, based on the Ascending Methods of Limits, each test item will be displayed at ten levels of difficulty in order to determine the threshold at which comprehension of contextual information occurred. In classical psychophysics, based on the Ascending Methods of Limits, stimulus features are first presented at an unnoticeable level. The intensity of the stimulus is progressively increased until the stimulus features reach a level that is noticeable which is known as the threshold (Gescheider, 2013). For the application used here, threshold referred to the level at which the question is first comprehended. The independent variables are levels of cognitive processing (three levels: *low, mid, high*) and categories of infographics (four categories: *data display, diagram, map, timeline*). The dependent variable is the level of difficulty at which participants comprehend contextual information.
In order to validate test items, neuropsychological tests that measure corresponding cognitive functions are also presented. We hypothesize that comprehending infographics will require integrating information by means of global processing. In addition, specific information extraction in local regions will not be sufficient to comprehend displays. Therefore, all test items are expected to be associated with global (holistic) processing, perceptual organization and visual reasoning. For each level of cognitive processing and each category of infographics the underlying cognitive functions are expected to be different from each other (details provided below).

**Hypotheses**

Three hypotheses are proposed, (1) all related to association of all infographics test items to context processing; (2) cognitive functions associated with the three cognitive levels; and (3) cognitive functions associated with the four categories of infographics. Each hypothesis was addressed with different sets of participants by administration of neuropsychological and infographics tests.

**Hypothesis 1. Infographics test will be sensitive to context processing, and test items will show internal consistency.** Reliability typically is used to examine whether the measurement tool provides consistent results if administered to the same group twice over of the course of time (test retest reliability), if administered by two scorers (interrater reliability); and whether each test item indicates the same construct (internal consistency) (Kimberlin & Winterstein, 2008; Laerdstatistics, 2015). In this study, internal consistency was determined by means of Cronbach’s alpha - i.e., how strong the items are associated to each other to determine the same underlying measure (Laerdstatistics, 2015). We hypothesize that a newly developed infographics test will show strong internal consistency (Field, 2009).
Construct validity indicates if the new test measures what we want to measure (Gregory, 2007). Convergent and divergent validities are the two types of construct validity. Convergent validity examines whether the construct in the newly developed items are highly associated with the similar construct measured by an established test. Divergent validity examines whether the construct in the newly developed items are weakly associated or not associated with the different construct measured by an established test (Gregory, 2007).

In this study, each test item is expected to be sensitive to context processing. Specifically, understanding information contained in infographics test items requires the use of perceptual organization and global processing, each of which are fundamental to context processing. Answering test questions requires perceptual organization, global processing, comparison across the images, and visual reasoning. Specifically, perceptual organization is required for visual integration of the visual variables (e.g. color, position, and size). Global processing by paying attention to details is required to compare and integrate visual variables. Based on this rationale, to determine construct validity, the newly developed infographics test is expected to correlate with tests of global precedence (Navon Global Precedence Test) (Navon, 1977), global processing by paying attention to details (WAIS-III Picture Completion) (Solomon et al., 2010; Wechsler, 1997b), visual- perceptual organization (The Hooper Visual Organization Test) (Hooper, 1983), visual reasoning (WASI-II Matrix Reasoning) (Groth-Marnat, 2003; Wechsler, 2011), attention (Trail Making Test A), and task switching (Trail Making Test B) (Reitan & Wolfson, 1985; Strauss, Sherman, & Spreen, 2006).

Extracting information from local regions of the test items is not expected to be sufficient to answer the questions. In such cases, participants would need more information or more time to answer questions correctly (the threshold would be higher), or answers would be wrong.
Therefore, we hypothesize that performance on infographics test items will not correlate, or be minimally correlated with, tests of local processing (Navon Local Processing and WASI-II Block Design) (Drake, Redash, Coleman, Haimson, & Winner, 2010; Drake & Winner, 2011; Navon, 1977).

**Hypothesis 2. Levels of processing will be associated with different cognitive functions.** We hypothesize that items at the three levels of cognitive processing will require specific cognitive functions.

Level 1 items, identifying associations among basic visual variables, such as color, size and shape, require comparing, contrasting and integrating these variables. Level 1 test items are expected to correlate with WASI-II Matrix Reasoning (Groth-Marnat, 2003; Wechsler, 2011).

Level 2 items, identifying associations among visual variables, icons (silhouettes representing real-world entities), and real-world applications, requires associating visual variables with their referents. Participants are expected to answer the questions by understanding context in real-world applications, and having higher vocabulary knowledge. Based on this rationale, the level 2 test items are expected to correlate with tests that require global processing, associated with real-world applications (WAIS-III Picture Completion Test) and visual organization (The Hooper Visual Organization Test) (Hooper, 1983), in addition to visual reasoning (WASI-II Matrix Reasoning) (Groth-Marnat, 2003; Wechsler, 2011).

Level 3 Items, identifying inferences and verbal reasoning, requires additional information beyond the visual variables, icons, and real-world applications. Participants are expected to answer questions by understanding context in real-world applications and have higher vocabulary knowledge, but also be able to categorize objects and thereby comprehend relationships that extend beyond image components. Based on this rationale, Level 3 items are
expected to correlate with tests of word knowledge (WASI-II Vocabulary) (Wechsler, 2011) and verbal reasoning (WASI-II Similarities) (Rozencwajg, 2007; Wechsler, 2011) in addition to visual organization (The Hooper Visual Organization Test) (Hooper, 1983), understanding context by paying attention to details (WAIS-III Picture Completion Test) (Solomon et al., 2010; Wechsler, 1997b), and visual reasoning (WASI-II Matrix Reasoning) (Groth-Marnat, 2003; Wechsler, 2011).

**Hypothesis 3. Cognitive functions will be associated with categories of Infographics.**

We hypothesize that the four categories of infographics used here (data display, diagrams, maps, and timeline) will depend upon specific aspects of cognitive functions, including spatial relations, sequencing, visuo-spatial working memory, and spatial orientation. In addition, some cognitive functions are expected to be associated with all categories, but to different extents.

For data displays, identifying information requires understanding trends and associations of quantitative information (Kosslyn, 1994; Malamed, 2009). Based on this rationale, data displays are expected to correlate with tests of graphical skills that contain quantitative information (Graphical Literacy Scale) (Galesic & Garcia-Retamero, 2011). For diagrams, identifying information requires understanding connections among qualitative entities. Because diagrams also include quantitative information, cognitive functions related to diagrams are likely to overlap with those related to data displays. However, diagrams require connecting visual variables through understanding connections. Based on this rationale, diagrams are expected to correlate with tests requiring understanding connections (WASI-II Matrix Reasoning) (Groth-Marnat, 2003; Wechsler, 2011).

For maps, identifying information requires understanding relations among the spatial representations of the real-world regions. Based on this rationale, maps are expected to correlate
more strongly with visual spatial perception (Judgment of Line Orientation Test) (Strauss et al., 2006).

For timeline, identifying information requires understanding relationships among events by means of sequencing and visuospatial working memory. Based on this rationale, timelines are expected to correlate more strongly with tests of sequencing and visuospatial working memory (WMS-III Spatial Span Test) (Strauss et al., 2006; Wechsler, 1997b).

Chapter 2: Method

The research study has proceeded in two phases: Phase 1-development of graphical test items. Phase 2- pilot testing and assessing test items to determine the specific cognitive functions associated with interpreting graphical displays.

Phase 1. Test Item Development

Test items were developed based on established design techniques for visual-spatial displays (Hegarty, 2011; Kosslyn, 1994; Tufte, 1983). Context was formed through perceptual comparison and global processing.

Graphic Design of Test Items

Test items were made up by the combination of icons, geometrical shapes, and graphical descriptors. Prior to development, the previous studies (Bateman et al. 2010; Cleveland & McGill, 1985; Haroz, Kosara, & Franconeri, 2015), pioneer books of information visualization (Cairo, 2013; Lowe & North, 2015; Malamed, 2009; McCandless, 2012; Munzner, 2015; Silver & Cook, 2014; Tufte,1983) and recognized websites (e.g., Vital, 2015; Yau, 2017) were carefully examined, and the most appropriate samples of infographics were utilized to create a mood board for design ideas. An example of an infographic is presented in Figure 1.
Each test item was designed in Adobe Illustrator Creative Clouds (Adobe Illustrator CC) (Adobe Systems, 2015). Colors were determined based upon nature of data used in each test item (e.g., sequential or qualitative), and hue (e.g., single hue or multiple hue) provided on a website that contained color schemes (Brewer, 2018; Harrower & Brewer, 2003). Hexadecimal (HEX) codes of the colors were utilized in Adobe Illustrator CC. Basic visual features (e.g., shape, size) along with graphs were drawn in Adobe Illustrator CC based on the design principles derived from visual variables (Bertin, 1983; Hegarty, 2011; Munzner, 2015), good and bad examples (Tufte, 1983), and empirical studies (Cleveland & McGill, 1985; Hegarty, 2011).

**Infographics Categories**

Infographics were classified by the type of relationships infographics represent (Malamed, 2009). Four categories of infographics were developed here are: (1) *data displays*, which demonstrated comparisons and connections of quantitative information; (2) *diagrams*, which showed the connection among qualitative information; (3) *timelines*, which demonstrated the sequential associations among temporal entities; and (4) *maps*, which displayed the relationship among spatial entities (Malamed, 2009).

**Level of Cognitive Processing**

Test items were divided into three levels of cognitive processing: (1) *Low-level* (through comparing visual variables, and which required global processing and visual reasoning), (2) *mid-level* (comparing visual variables that refer to real world examples, and which required visual reasoning and global processing related to the real-world applications), and (3) *high-level* (comparing visual variables that refer to real-world examples, and which also required categorization that is based upon visual and verbal reasoning). Twelve items were developed for each processing level (comprised of three examples of each of the four categories of
infographics), for a total of 36 test items. Appendix A displays the test item number, images, corresponding level of processing, and category of infographics. Table 1 displays the summary of level of cognitive processing and category of infographics (explained below) for each item.

**Low-level processing (Level 1).** Test items at Level 1 were based upon the combination of basic stimulus features, such as color, size, and shape, which demonstrated global processing, perceptual organization, and visual reasoning. Level 1 items thereby emphasized fundamental perceptual relationships among stimulus features. Figure 2a, Figure 2b, and Figure 2c depict three examples of Level 1 test items.

**Mid-level processing (Level 2).** Test items at Level 2 were based upon the combination of basic stimulus features (color, size, and shape) as well as icons representing real-world examples. In this way, Level 2 test items included the application of stimulus relationships to identifiable real-world situations. Icons used in the test items were downloaded from an online platform (The Noun Project, n.d.) and embedded into the test items in Adobe illustrator CC. Figure 3a, Figure 3b, and Figure 3c depict three examples of Level 2 test items.

**High-level processing (Level 3).** Test items at Level 3 were based upon the combination of basic stimulus features, icons representing real-world applications, as well as additional cognitive processing that required verbal reasoning and categorization. For Level 3, some forms of information were contained directly in the graphic, as occurred with Level 1 and 2 items, whereas additional information required verbal reasoning and categorization. In other words, interpreting Level 3 items required cognitive activities that allowed observers to generalize different objects in the same way in order to comprehend information beyond the visual variables given in the display (Rozencwajg, 2007). Icons and maps used in the test items were downloaded from online platforms (Free SVG Maps, n.d.; The Noun Project, n.d.; Wikipedia: Blank maps,
n.d.), and embedded into the test items in Adobe illustrator CC. Figure 4a, Figure 4b, and Figure 4c depict three examples of Level 3 items.

**Item Questions**

Fundamentally, each test item contained information that was constructed from the context of the infographics. The interpretation of graphical displays was assessed through questions about information contained in the test item. This technique has been used previously for the analysis of chart comprehension (Bateman et al., 2010). Infographic items and their associated questions were designed to require the use of context to answer the question. Specifically, information across the image needed to be integrated, by recognizing global relationships and comparisons, in order to answer the questions. Information contained in the image at local regions, which contained specific information in detail, was not sufficient to answer the questions. Appendix A displays all item questions along with their answers.

**Red Herrings (Task-irrelevant Features)**

In addition to visual components relevant to item questions, graphics also contained visual features that were task-irrelevant (red-herrings). Task irrelevant features (red herrings) served as distractors to prevent the participants from using task relevant information as local cues.

**Levels of Difficulty for Each Test Item**

In order to index participants’ ability to interpret graphical displays, relevant visual information varied in saliency (i.e., contrast of a stimulus feature or relationship) across trials, beginning with the most difficult level. In this way, critical visual information was made progressively more salient by increasing contrast of the relevant components. Participants' ability to use contextual information was indexed as a “threshold” of comprehension, based upon an
Ascending Method of Limits procedure (Gescheider, 2013). In this study, threshold referred to the difficulty level at which information contained in the graphics can first be comprehended. To accomplish this, each test item was varied along a specific stimulus dimension (e.g., the contrast of color, or the thickness of a connecting line). Levels of difficulty were based upon design principles such as principle of discriminability and principle of salience (Hegarty, 2011; Kosslyn, 1994; Munzner, 2015; Ware, 2012).

Changes varied in detectability based on the principle of discriminability, which states that changes within a visual variable should be detectable (Hegarty, 2011; Kosslyn, 1994; Munzner, 2015; Ware, 2012). In this study, each test item was presented at 10 levels of difficulty. An example of levels of difficulty for each level of processing is presented in Figures 5a, 5b, and 5c, respectively. The principle of salience was used to make the task-relevant information more noticeable (Bertin, 1983; Hegarty, 2011; Kosslyn, 1994). Contrast was created by including visual variables (e.g., size, shape, color) upon which the comparison was made, and saliency of relevant information was increased by increasing the contrast of this variable. The most difficult level thereby corresponded to lower contrast. In this study, although task-relevant components increased progressively in salience, task-irrelevant (red herrings) varied randomly and contained information relevant to the item question. In order not to form local cues, in each level, the location of certain features (e.g., a row, or a column) changed randomly.

In Figure 5a, the task-relevant information is the thickness of lines among the same colored dots. Contrast is progressively increased by increasing the relative thickness of connecting lines. Task-irrelevant information is the thickness of lines among different colored dots. In order for the shapes formed by dots not to serve as local cues, location of dots along with the lines have been changed across the levels.
In Figure 5b, the task-relevant information is the number of fish in Jim’s pond at sunset. Contrast is progressively increased by increasing the number of fish at this intersection of Jim’s pond and sunset. Task-irrelevant information is the number of fish in different ponds at different times of day. In order for the set of rows not to serve as local cues, location (order) of each row has been changed across the levels.

In Figure 5c, the task-relevant information is the number of cigarettes and pipes, and task irrelevant information is the number of bottles of beer and wine. Contrast is progressively increased by increasing the difference between the number of task-relevant and task-irrelevant features. In order for each color in the regions not to serve local cues, color of each region was varied across the levels and number of items have changed in each region (see Figure 5c).

**Phase II. Testing**

Testing proceeded in two phases: pilot testing and testing for reliability and validity of the test items. One hundred sixty-one (161) participants were enrolled in this study combined with pilot and testing phases.

**Pilot Phase**

Items were developed based on a cycle of iterative testing along with participants’ feedback to create optimal perceived tasks. During the item development stage and the determination of the appropriate neuropsychological test, more than one pilot test was administered to a total of 32 participants.

**Pilot 1.** The first pilot study consisted of 8 participants, including three women and five men between the ages 25 and 40. There were only two tasks from two levels of cognitive processing for a total of four items.
Pilot 2. The second pilot study consisted of 12 participants, including six women and six men between the ages of 24 and 65. Ten items from level 1, ten items from level 2, and four items from level 3 were administered for a total of 24 items. In this set of data, the threshold for each level was determined and feedback from participants was received to iterate the test items.

Pilot 3. The third pilot study consisted of 12 participants, including seven women and five men between the ages of 18 and 54. Thirty-six items along with the four practice questions were administered to examine the neuropsychological tests that tap into the corresponding cognitive functions and to determine the final version of the test items.

Testing Phase

The reliability and validity of the infographic test items were analyzed by measuring comprehension thresholds, as well as through a series of standardized neuropsychological tests administered to 129 participants.

A group of 129 participants was recruited to participate in the testing phase. Participants aged 18-40 were recruited from the Brooklyn College Psychology Department participant recruitment system, which draws students from the Introductory Psychology courses. Participants served either as volunteers or were provided with research credits to be applied to the course. Participants were screened for visual acuity (20/30 or better using 14” binoculars Snellen test) (Snellen, 1873) and color vision (using Ishihara Test for Color Blindness) to rule out vision deficiencies (Ishihara, 1972, 1987). All participants who have corrected vision were screened for visual acuity while wearing contact lenses or eyeglasses (best-corrected acuity). In addition, participants were asked whether they had previous eye surgery or an ophthalmologic disorder. All participants used their best corrected vision. No participant was ruled out due to color blindness or visual acuity problems. Participants were provided with informed consent
forms before they participated in accordance with regulations of the Institutional Review Board (IRB) for Human Research at Brooklyn College.

**Demographic Measures**

Demographic questions were developed to document participants’ date of birth, education level, gender, native language, handedness, best-corrected visual acuity, whether they used their best corrected vision the day of the study, whether they have an ophthalmologic disorder, and whether they have previously attended a class in statistics (which may have provided additional experience with interpreting graphical information).

**Self-assessment questions on reading graphs**

Likert type scale questions were developed to document how well participants consider their graph, map, diagram and timeline comprehension to be. A sample instruction and question are presented below:

Sample instruction: “You need to answer the following questions on a 7-point- Likert scale 1=not at all 7=very well”.

Sample question: “How good are you at reading maps (e.g., road maps)?”

**Answer spreadsheet for the examiners**

The experimenter had a spreadsheet that contained a list of test items, including the level of cognitive processing, name of the items, questions, correct answers, and sample images. Three columns were available for examiners to report the level of difficulty that identified participants' threshold of comprehension, participant’s actual responses, and participant’s feedback for each item.

**Prompts and queries throughout the administration**
Based on procedures used in Wechsler Abbreviated Scale of the Intelligence (WASI-II) (Wechsler, 2011), prompts and queries related to test items and to task-relevant and task-irrelevant responses were provided during the administration process. The prompts and queries are presented in Appendix B.

**Practice Questions**

At the beginning of testing, a general practice question was provided to ensure that participants comprehended how levels of difficulty varied across the levels. A specific practice question was provided for each level of processing. Each practice question contained task-relevant and task-irrelevant features. The answers to practice questions were explained in detail by the experimenter to ensure that participants understood how to look globally to answer the questions. After each practice question, detailed instructions were provided regarding the subsequent test. Appendix A includes the practice questions.

**Test Assessments**

**Infographics Assessment**

The test items were presented by using Microsoft Powerpoint presentation software on a Macbook air 13.3 (1440 x900) computer. Each test item was placed at the center of each slide and time spent on each slide has been set previously for five seconds. Participants were first allowed to read item questions and study corresponding figure legends at least five seconds (additional time was provided if needed). The question and figure legends were presented with each level of the graphical display. Items then appeared for five seconds, followed by five seconds of blank screen. The next level of the test item then appeared, followed by another five seconds of blank screen. This procedure continued until all 10 levels of difficulty were displayed. Because mean level differences among the performance on levels of processing were not tested
and short-term carry over effects were expected, the order of three levels of processing was presented in a predetermined (fixed) order (Bell, 2012). For each cognitive level, three items corresponded to each of the four types of infographics. Multiple versions of test packages were prepared to present the items in each level of difficulty in a randomized order. Each level of processing was measured in a block, starting with Level 1. The difficulty level at which the participants first provided an acceptable answer within five seconds of image presentation or the following five seconds of blank screen served as the correct answer. Some parts of the instructions were provided verbally while others were provided in a visual format on the slides. Because instructions for general rules of test administration as well as specific rules for each level of cognitive processing were provided in a mixed format, a separate file that included both verbal and visual instructions was prepared for the examiners, as seen in Appendix B.

In order for the participants not to mix the term “level of cognitive processing” with “level of difficulty”, each level of cognitive processing was called a “subtest” during task administration. Participants were expected to inhibit task-irrelevant features (red herrings) and focus on task relevant features by using global processing to answer each question correctly. The most difficult test item was presented first. Participants attempted to answer the item question at any point during the sequence of stimulus presentation. The experimenter kept track of participants’ responses until the correct answer was provided. Prompts and queries were provided if necessary. Once participants gave the correct answer, the experimenter pressed the corresponding button on the computer to stop the sequence and skip the rest of the levels of difficulty, and reported the levels of difficulty at which participants responded correctly and the correct verbal response on the answer sheet. Participants needed to answer questions correctly in order to move on to subsequent items. Instructions are provided in Appendix B.
**Scoring of the Infographics Test Items**

Scoring was established from 1 (easiest level) to 10 (hardest level). A score of 11 was assigned if participants failed to answer a question in timely manner (within 10 levels), or they started answering the question after a five second period of white page of level 10, or they did not understand the question.

**Neuropsychological Assessment**

Administration of the test items was followed by administration of neuropsychological tests. The neuropsychological tests were administered as established tests that tap into similar construct to assess construct validity of the innovative test. Additional neuropsychological tests were provided to examine the underlying cognitive functions for each level of cognitive processing and each category of infographics. Because a relatively large number of neuropsychological tests were utilized, participants’ limited attention span, and restricted time provided for each participant (maximum 2 hours per each participant) did not enable all neuropsychological tests to be administered to each participant. Therefore, a set of neuropsychological tests were prepared for each hypothesis and one of three sets of study materials was assigned randomly to each participant.

Table 2 summarizes the neuropsychological tests used to tap the cognitive functions related to each study hypothesis including domains of visual attention, spatial working memory, visual organization, verbal reasoning, and word knowledge.

**Trail Making Test (TMT)**. This test was first developed in 1938 and was included in the Army Individual Test of General Ability in 1944. Subsequently, it became a part of Halstead-Reitan Battery  (Reitan & Wolfson, 1985; Strauss et al., 2006). In this study, Parts A and B were used to examine visual attention and task switching, respectively (Reitan & Wolfson, 1985;
Tombaugh, 2004). In Part A, participants were required to connect numbers embedded in circles sequentially. In Part B, participants were required to connect numbers and letters embedded in circles alternately. Administration time was 5-10 minutes depending on the participants’ performance. Time spent during each part to complete the test was recorded. If a participant made an error, the experimenter addressed the error and guided the participant to continue from this circle. Measurement of test duration included time spent on error trials (Strauss et al., 2006).

**Navon Global Precedence and Local Processing Task.** This task was first developed by Navon (1977) to measure global precedence. In the current study, a computerized version of the Navon task, which was created by PsyToolkit developer Gijsbert Stoet, was used to measure both global precedence and local processing (Stoet, 2010). Letters in large sized form (global level) or small sized form (local level) were shown for 4 seconds. Participants were required to press buttons on a keyboard based upon their detection of a letter H or O at the local (letters in small size) or global level (letters in large size) on each trial, for a total of 50 trials. Reaction time on correct answers and errors were recorded at the end of the session (Stoet, 2010).

**The Hooper Visual Organization Test.** This test was developed by Hooper in 1958 to measure visual-spatial ability, visual organization, and object naming. In addition to visual organization, it requires vocabulary skills (Hooper, 1983; Strauss et al., 2006). The test included original 30 items given on a test booklet. Each item was formed by pieces of objects and presented in a mixed order on the booklet. Participants were required to visually organize and construct the corresponding pieces and subsequently name the objects. Administration time was 10-15 minutes (Strauss et al., 2006).

The Hooper Visual Organization Test has Scoring Key that tracks picture number, participant responses, pre-determined full credit (1 credit) responses, ½ credit responses, and no
credit responses. As indicated in the manual, synonyms and answers close to the full-credit responses were counted as 1 credit (Hooper, 1983). Responses that did not meet criteria for full-credit were counted as ½ credit. Incorrect responses were counted as 0. In order to increase objectivity in scoring process, an online dictionary website was utilized to identify synonyms (Airplane, 2018; Table, 2018). Two highly trained scorers, independently scored test items. If there was a disagreement, a third scorer was used to arrive at a final decision. As indicated in the manual, because corrected raw scores only correspond to participants’ aged 25-69, and this study utilized younger participants, instead of using corrected raw scores, total raw scores were used. Because qualitative interpretation such as isolate responses, perseverative responses, a bizarre response, neologistic response are usually utilized to differentiate right hemisphere impairment from left hemisphere impairment (Hooper, 1983) and in this study included only healthy individuals, only quantitative interpretation was accepted in scoring. Total raw scores ranged from 0-30.

**Wechsler Abbreviated Scale of Intelligence-Second Edition** (WASI-II; Wechsler, 2011). This scale was the abbreviated version of the intelligence test that is commonly used to estimate intelligence quotient (IQ) (Wechsler, 2011). However, in the current study instead of taking the total intelligence score into account, each subtest was administered as a separate cognitive test. The subtests of WASI-II are explained below:

**Matrix Reasoning.** This test assessed visual reasoning, abstract problem solving, spatial ability, and perceptual organization (Groth-Marnat, 2003; Wechsler, 2011). Participants were required to solve each of 30 matrix problems through recognizing missing sections on visual patterns by means of choosing one of five options provided on the test stimuli booklet. Based on the discontinue rule, if a participant answered three questions incorrectly in a row, the test was
stopped. The total number of correct answers was recorded, and ranged from 0-30 (Ragni, Stahl, & Fangmeier, 2011; Wechsler, 2011).

**Block Design.** This test assessed local processing and analyzing and synthesizing abstract visual stimuli. This test consisted of 13 items made up of visual patterns given on a booklet along with cubes that participants used to construct the patterns. Based on the discontinue rule, if a participant did not construct the two patterns correctly in a row, the test was discontinued. Accuracy and time spent to complete each item determined the obtained total score.

Although in the WASI-II manual, Block Design was accepted as a measure to test the ability to analyze and synthesize abstract visual stimuli (Wechsler, 2011), previous studies also administered this test to measure local processing (Drake, Redash, Coleman, Haimson, & Winner, 2010; Drake & Winner, 2011). Thus, in the current study, this test was used to measure local processing.

**Similarities.** This test assesses verbal reasoning, concept formation, and categorization. A list of words consists of concrete and abstract words, for a total of 24 items. Participants were required to find the similarities (common features) between each of two words (Rozenewajg, 2007; Wechsler, 2011). During administration, if the responses were not clear, queries were provided (e.g., What do you mean?); if separate features of the two words were responded to instead of common features, prompts (e.g., Yes, but what are they?) were provided. Each item was scored as 2, 1, or 0. Based on the discontinue rule, if a participant obtained 0 for two questions in a row, the test was stopped. Each response had to be compatible with the predetermined response list. If the responses were not consistent with the list, subjective judgment was utilized to determine the equivalent words (Wechsler, 2011). In order to increase
objectivity in scoring, two scorers independently scored test protocols. If two scorers did not agree on the same response, a third scorer was used to arrive at a final decision (Belshaw, Asher, Harvey, & Dean, 2015). The total number of correct answers was calculated, and ranged from 0-45.

**Vocabulary.** This test assessed word knowledge, verbal concept formation, and the ability to use words appropriately by having participants define 31 words. The total number of correct responses was recorded as a performance score (Wechsler, 2011). As mentioned in the WASI-II Similarities Test, during the administration of the Vocabulary test, queries and prompts were provided if necessary. Based on the discontinue rule, if a participant obtained 0 for two questions in a row, this test was stopped. During scoring, the response had to be compatible with the predetermined list. If not, scorers used subjective judgment. If the response provided a clear and understandable explanation, 2 points were assigned. If the response failed to meet the criteria of the content of the predetermined response, 1 point was assigned. If the response was unclear, 0 was assigned. If two scorers did not agree on the same response, a third scorer was used to arrive at a final decision (Belshaw et al., 2015).

**Picture Completion Subtest of Wechsler Adult Intelligence Scale-Third Edition (WAIS-III).** was used to examine global processing through understanding context of a real-world situation by paying attention to details (local parts) (Vanclef, n.d.). For each of 25 pictures, participants had a maximum of 20 seconds to point out or name the important part of the picture that was missing. The total number of correct answers were recorded (Solomon et al., 2010; Wechsler, 1997b). As indicated in the Hooper Visual Organization Test, WASI-II Similarities, and WASI-II Vocabulary tests, because verbal response was also crucial for the Picture
Completion subtest, this test was scored by two scorers and a third scorer was utilized in cases of disagreement between the two scorers.

**Graph Literacy Scale.** A graph literacy tool was developed to assess whether participants could understand graphs and quantitative visual displays (Galesic & Garcia-Retamero, 2011). This measurement was used to test graph literacy skills for 13 questions. Participants were required to answer specific questions from the graph, association between two data points, and interpret results beyond the data given in the graph (Galesic & Garcia-Retamero, 2011). The number of total correct responses served as the performance score. Because in this study data display served as one of the categories of infographics, the graph literacy scale was used as one of the measurements to test the validity of this category of infographics.

**Judgment of Line Orientation Test (JLO).** This test was developed by Benton, Sivan, desHamsher, and Varney in 1994 to measure spatial perception and spatial orientation. The test consists of 30 items that have a stimulus card formed by two angled lines and response cards formed by 11 lines on the subsequent page. Participants are required to match the two angled lines to the lines in the response card. There are two forms: *H* and *V*. In each form the same items are displayed but in a different order. In this study, one of the two forms was randomly assigned to participants. The total number of correct answers was obtained at the end of the test, and ranged from 0-30 (Strauss et al., 2006).

**Spatial Span of Wechsler Memory Scale-Third Edition (WMS-III).** This test measures spatial working memory, and consists of a spatial span board made up of cubes and a response booklet. The experimenter points to numbers on a board depending on the order given on the response booklet and the participant subsequently points to numbers either in the same order (forward subtask) or in the reverse order (backward subtask) based upon the instruction.
The sequence of numbers gradually increases in each trial. A spatial span test total score is obtained by calculating the total number of correct responses for the forward and backward subtasks (Strauss et al., 2006; Wechsler, 1997b).

**Chapter 3: Results**

Prior to the reliability and validity testing, the data of 129 participants were examined. Some data were excluded due to the data entry errors, measurements errors or unusual values (LaerdStatistics, 2015).

**Data Exclusion Criteria**

**Data entry errors.** There was only one value (WASI-II Matrix Reasoning score) typed incorrectly. Although the score range was 0-30, 70 was entered by mistake on the excel file, whereas in the original documents indicated 17.

**Measurement errors.** Measurement errors were caused by incorrect administration of infographics or neuropsychological tests. Because these errors could not be corrected, data were partially or fully removed from the data set (see Table 3).

**Full data removal.** As seen in Table 3, test scores of 14 participants were not included in the analyses (for various reasons). The hardcopy test files of eight participants included confusing entries (therefore discarded). In addition, one participant was excluded due to incorrect administration order and five participants were excluded due to incorrect administration of Infographics.

**Partial data removal-Infographics test items.** Because some features of the items (e.g., questions in items) changed after the administration has started, 31 data scores were not included in the dataset.
Partial data removal-neuropsychological test items. Some of the neuropsychological test scores of 36 participants were excluded from the data analysis due to measurement errors (not administered by administration rules). As seen in Table 3, the data of WMS-III Spatial Span Test scores of 21 participants, WASI-II Matrix Reasoning scores of two participants, and TMTB scores of two participants were excluded due to incorrect administration. The data of WASI-II Similarities, WASI-II Vocabulary, and WAIS-III Picture Completion Test of 11 participants were excluded due to being administered without prompts and queries. Navon Global Precedence and Navon Local Processing Test scores of 4 participants were accidentally not saved on the computer.

Unusual values. The unusual values (e.g., outliers based on z scores or boxplots) for each test item were kept in the descriptive analysis. However, unusual values were removed to meet the assumptions of parametric statistics for further analysis and they were excluded accordingly. Detailed information is provided below.

In sum, after excluding the data cells, 115 participants were included in the analysis, out of an initial 129 participants.

Descriptive Statistics for Demographic Measures

The mean age of participants was 23.39 ($SD = 4.92$) (min = 18, max = 40). There were 83 women and 32 men, for a total of 115 participants. All participants were college students. There were 105 right-handed participants, eight left-handed participants, and two participants reported equivalent use of both hands. All participants used their best corrected vision. Only two participants had ophthalmologic surgery (i.e., retina attachment surgery and retinal detachment surgeries). Because these individuals did not have any current ophthalmologic disorders and did not deviate significantly from other participants, their data were included.
English was the first language of 61 participants, 41 participants were bilingual, 11 participants knew more than two languages, and for two participants this information was not available.

A total of 57 participants had attended a college statistics class while 53 participants did not. Additionally, three participants were currently taking the statistics while completing the current study. Two participants had completed a high school statistics class.

Descriptive statistics were calculated and histograms of number of responses for each threshold level were displayed for each item separately. Floor and ceiling effects were examined to determine the ease and difficulty of items (Dean, Walker, & Jenkinson, 2018).

Descriptive Statistics for Each Test Item

There were 115 participants included in the analysis to test the normality of the distribution. Table 5 presents means, standard deviations, and minimum and maximum values for each test item.

Test Item Difficulty

Ceiling and floor effects. Ceiling and floor effects for each test item were determined based upon the percentage of participants who answered test item questions at the easiest level of difficulty, or who could not answer questions correctly at any level of difficulty, respectively (Dean et al., 2018). Ceiling effects were based upon the percentage of the participants who responded with “1” (answered the test item question correctly at the first level of difficulty). Floor effects were based upon the percentage of participants who answered with “11” (could not answer the test item question).

As shown in Figures 6a, 6b, and 6c sample histograms present how test item difficulty varied from item to item. Based upon the bottom 29 % of responses (number of 11’s)
al., 2018), one item (Level 1 Item 4) (diagram) was identified as having a floor effect (see Figure 6a).

**Normality test for raw scores.** Normality tests were performed based on Shapiro Wilk test (Shapiro & Wilk, 1965), Fisher skewness coefficient (dividing skewness values to standard errors of skewness) (Kim, 2013), and visual examination of histograms (LaerdStatistics, 2015).

Kim (2013) discussed that visual examination or Shapiro Wilk test can be used to determine the normal distribution in large sample sizes and small to medium sample sizes, respectively. Due to the discrepancy between the results of visual examination and Shapiro-Wilk test, Fisher’s Skewness Coefficient can be accepted as a good indicator of the normal distribution (Kim, 2013).

Fisher skewness coefficient (dividing skewness values to standard errors of skewness) was calculated (Kim, 2013). Due to the mixed values of z critical in the literature (Kim, 2013; West, Finch, & Curran, 1995), ±1.96 was accepted as a z critical value (Pett, 2015). The test items that contained Fisher skewness coefficient beyond ±1.96 range were accepted as non-normal distributed items. As seen in Table 5, items that are red highlighted in the Z skewness column were accepted as non-normally distributed, and data transformation was performed accordingly.

**Data transformation.** Based upon Tabachnick and Fidell (2007) and Howell (2007) (see Table 4), data transformation was performed on each test item that failed to meet the criteria for a normal distribution (Laerdstatistics, 2015).

**H1. Reliability and Validity Testing**

Reliability and construct validity testing were carried out based on previous studies (Chahoud, Chahine, Salameh, & Sauleau, 2017; Gerson, 1974; Johnstone & Wilhelm, 1997;
Sanchez-Cubillo et al., 2009; Tanabe & Osaka, 2009; Torfs, Vancleef, Lafosse, Wagemans, & De-Wit, 2014).

**Test Reliability (Internal Consistency) (Cronbach’s alpha)**

Cronbach’s alpha was measured to test the internal consistency of the test items. We included 84 cases in the reliability analysis. Because some test items changed in the beginning of the tests, out of 115 cases, 31 cases were accepted as missing values in the dataset.

Acceptable values are typically 0.7 or higher (DeVellis, 2003; Kline, 2005). In this study, Cronbach’s alpha was 0.837, which was a high level of internal consistency for the scale, for a total of 36 items.

**Test Validity (Convergent and Divergent Validity)**

Exploratory correlation analysis (Sanchez-Cubillo et al., 2009) was used to test the convergent validity and divergent validity, which served to assess construct validity (Johnstone & Wilhelm, 1997).

**Exploratory Correlation Analysis**

Exploratory correlation analysis was performed to see whether there were significant associations among the neuropsychological tests and infographics (Sanchez-Cubillo et al., 2009). One of the assumptions of parametric statistics is to include normally distributed test item scores in the analysis.

**Descriptive Statistics of Infographics Scores**

Prior to averaging test item scores for correlation analysis, each item was examined for normality. Because the distribution of some test items was not normally distributed (based on Fisher’s skewness coefficient) (see Table 5), data transformation was performed by means of the formulae displayed in Table 4. Each score then was converted to a z score, and average z scores
were used in correlation analysis. Visual inspection of histograms revealed one unusual value which may represent an outlier, and it was removed from the data.

Descriptive statistics were then calculated (see Table 7) and histograms of average responses were generated (Figure 7). A normality test was performed based upon Fisher skewness coefficient (Kim, 2013) and visual examination of histograms (LaerdStatistics, 2015).

**Descriptive Statistics of Neuropsychological Test Scores**

Descriptive statistics and normality tests for each neuropsychological variable were calculated for both raw scores and z scores. Table 6 displays descriptive statistics for each neuropsychological test.

**Prerequisites for Parametric Statistics (Pearson Correlation Analysis)**

Prerequisites for parametric statistics were tested prior to deciding whether Spearman or Pearson correlation analyses should be conducted. Variables that met the required prerequisites were accepted for Pearson correlation analysis. If assumptions were not met, non-parametric statistics (Spearman) were conducted (LaerdStatistics, 2015). To meet the assumptions of parametric statistics, linear relationship between two variables and outliers were examined by investigating the scatter diagrams. After the outliers were eliminated, based upon scatter diagrams, linear relationships were again examined. This data set was used for correlation analysis.

**Correlation Analyses**

In order to test the convergent validity in Hypothesis 1, we predicted that the Hooper Visual Organization Test, WAIS-III Picture Completion, WASI-II Matrix Reasoning (tests of accuracy) would negatively strongly correlate with Infographics, TMTA, TMTB; also, we
predicted that Navon Global Precedence (tests of response time) would positively correlate with Infographics.

Pearson correlation results showed a statistically significant, negative correlation between Infographics and the Hooper Visual Organization Test \((r = -0.482, p = 0.011, n = 27)\), WASI-II Matrix Reasoning \((r = -0.373, p < 0.001, n = 112)\) and WAIS-III Picture Completion \((r = 0.428, p = 0.033, n = 25)\) (see Table 8a).

There was no significant correlation between Infographics and TMTA \((r = 0.276, p = 0.173, n = 26)\), TMTB \((r = 0.297, p = 0.169, n = 23)\), or Navon Global Precedence \((r = 0.088, p = 0.675, n = 25)\).

For hypothesis 1, we predicted that Infographics would not correlate with Navon Local Processing and WASI-II Block Design. This hypothesis was supported and the relationships did not exist; Navon Local Processing: \((r = -0.133, p = 0.526, n = 25)\); WASI-II Block Design: \((r = -0.156, p = 0.428, n = 28)\).

Although not predicted, significant correlations were found between Infographics and Similarities \((r = -0.637, p < 0.001, n = 26)\), WASI-II Vocabulary \((r = -0.492, p = 0.015, n = 24)\), and the Graphical Literacy Skills Scale \((r = -0.449, p = 0.002, n = 47)\). The correlation between Infographics and Benton Judgment of Line of Orientation was closer to significance, \((r = -0.284, p = 0.056, n = 46)\). Because scatter diagrams displaying the relationship between Infographics and Graphical B and C subscales indicated that the assumptions of parametric statistics were not met, a Spearman’s rank order correlation was conducted. Results indicated a statistically significant correlation between Infographics and Graphical B \((r = -0.361, p = 0.013, n = 47)\) and Graphical C \((r = -0.354, p = 0.015, n = 47)\) (see Table 8b).
In sum, significant correlations were found between Infographics and the Hooper Visual Organization Test, WASI-II Matrix Reasoning, WAIS-III Picture Completion, Graphical Literacy Skills Scale, WASI-II Similarities, WASI-II Vocabulary, Graphical B and C subscales. Significant correlations were not found for the Infographics Test and TMTA, TMTB, Navon Global Precedence, Navon Local Processing, and WASI-II Block Design.

**Linear Regression Analyses**

In order to determine how much each neuropsychological test accounted for the variability in Infographics, linear regression analyses were conducted only on the variables that were significantly correlated with Infographics (Sanchez-Cubillo et al., 2009; Weisberg, 2014). The Hooper Visual Organization Test significantly predicted Infographics, $F(1, 25) = 7.57$, $p = .011$, and explained 23.2% of the variation in Infographics, with adjusted $R^2 = 20.2\%$. WASI-II Similarities significantly predicted Infographics, $F(1,24) = 16.370$, $p < .001$, accounting for 40.6% of variability in Infographics, with adjusted $R^2 = 38.1\%$. WASI-II Vocabulary significantly predicted Infographics, $F(1, 22) = 7.040$, $p = .015$, and explained 24.2% of the variability in Infographics with adjusted $R^2 = 20.8\%$. WASI-II Matrix Reasoning significantly predicted Infographics, $F(1, 110) = 17.817$, $p < .001$, and explained 13.9% of the variability in Infographics with adjusted $R^2 = 13.2\%$. WAIS-III Picture Completion significantly predicted Infographics, $F (1, 23) = 5.154$, $p = .033$, accounting for 18.3% of the variability in Infographics with adjusted $R^2 = 14.8\%$. Graphical Literacy Skills Scale significantly predicted Infographics, $F (1, 45) = 11.367$, $p = .002$, accounting for 20.2% of the variability in Infographics with adjusted $R^2 = 18.4\%$.

**Multiple Regression Analyses**
In order to determine how much variance in Infographics was explained by neuropsychological test scores (the corresponding neuropsychological tests taken together) as a predictor and to examine the unique contribution of each neuropsychological test to the prediction, multiple regression analyses were conducted only on the variables that were significantly correlated with Infographics (Sanchez-Cubillo et al., 2009; Weisberg, 2014). In this study, because one of three different sets of neuropsychological tests were administered to each participant, predictors included in multiple regression analyses varied accordingly. Infographics was predicted significantly based upon the Hooper Visual Organization Test and WASI-II Matrix Reasoning Test, \( F(2, 24) = 4.149, p = .028 \), and explained 25.7% of the variation in Infographics, with adjusted \( R^2 = 19.5\% \). However, none of the variables uniquely contribute to the variability in Infographics, \( p > .05 \). Infographics was statistically significantly predicted based upon WASI-II Similarities, WASI-II Vocabulary, WAIS-III Picture Completion, and WASI-II Matrix Reasoning, \( F(4, 18) = 3.549, p = .027 \), and explained 44% of the variation in Infographics, with adjusted \( R^2 = 31.6\% \). However, none of the variables did not significantly contribute to the prediction. Infographics was statistically significantly predicted based upon Graphical Skills Scale and WASI-II Matrix Reasoning, \( F(2, 42) = 6.280, p = .004 \), and explained 23% of the variation in Infographics, with adjusted \( R^2 = 23\% \). Only Graphical Skills Scale uniquely contribute to the model.

**H2. Cognitive Functions underlying Each Level of Cognitive Processing**

**Cognitive Functions Associated with Level of Cognitive Processing**

In order to examine the cognitive functions associated with each level of cognitive processing, correlation analyses were conducted between each level of cognitive processing and neuropsychological tests (Sanchez-Cubillo et al., 2009). Each level of cognitive processing
consisted of 12 test items. Thus, the average of 12 items for each level of cognitive processing was planned to be calculated.

**Descriptive Statistics for Each Level of Cognitive Processing**

The assumptions for parametric statistics were first tested. Prior to determination of average score of each cognitive level, each test item was examined for normality. We found that the distribution of each test item was not normally distributed, and therefore data transformation was performed based on the red highlighted values seen in Table 5, and each score was converted to a z score. The average z scores were then used in analyses.

Prior to conducting correlation analyses, descriptive statistics for each level of cognitive processing were determined separately. Descriptive statistics were calculated through removing only 1 test item (Level 1 Item 4) based upon the floor effect (Table 7).

**Normality Tests for Infographics Results at Each Level of Cognitive Processing**

Normality tests were performed based on Fisher skewness coefficient (dividing skewness values to standard errors of skewness) (Kim, 2013) as well as visual inspection of histograms (LaerdStatistics, 2015). Figure 8a and 8b present Level 1 and 2 histograms, respectively. Visual examination of Level 3 histogram revealed one unusual value, which may represent an outlier and was removed from the data for further analysis (Figure 8c).

**Prerequisites for Parametric Statistics**

Prerequisites for parametric statistics were tested prior to making decisions of whether to use Spearman or Pearson correlation analyses. Only variables that met prerequisites were included in the Pearson correlation analyses.

**Correlation Analyses**
Correlation Analyses were conducted between each level of cognitive processing and corresponding neuropsychological tests (see Table 9a and 9b).

**Level 1 Infographics.** For cognitive functions associated with Level 1 Infographics, results indicated a significant correlation between WASI-II Matrix Reasoning and Level 1 Infographics. \( r = -.223, p = .018, n = 112 \). Although not expected, we found significant correlations between Level 1 Infographics and WASI-II Similarities \( r = -.403, p = .041, n = 26 \), WAIS-III Picture Completion \( r = -.441, p = .027, n = 25 \), and Benton Judgment of Line Orientation \( r = -.328, p = .026, n = 46 \).

**Level 2 Infographics.** For cognitive functions associated with Level 2 Infographics, significant correlations were predicted between Level 2 Infographics and WAIS-III Picture Completion as well as the Hooper Visual Organization. The hypothesis was partially supported. The Hooper Visual Organization was significantly correlated with Level 2 Infographics \( r = -.542, p = .003, n = 27 \), but WAIS-III Picture Completion was not \( r = -.263, p = .204, n = 25 \). We found a significant correlation between WASI-II Matrix Reasoning and Level 2 Infographics \( r = -.361, p < .001, n = 112 \).

Although not predicted, significant correlations existed between Level 2 Infographics and TMTA \( r = .396, p = .045, n = 26 \), WASI-II Similarities \( r = -.599, p = .001, n = 26 \) and Graphical Literacy Skills Scale \( r = -.492, p < .001, n = 47 \). The relationship between Level 2 Infographics and the Graphical B and C subscales were not linear. Therefore, Spearman’s rank-order correlation was used, which showed significant correlations \( (r_s = -.358, p = .014, n = 47); (r_s = -.422, p = .003, n = 47) \).

**Level 3 Infographics.** For Level 3 Infographics, strong correlations were expected between Level 3 Infographics and WASI-II Similarities as well as WASI-II Vocabulary. This
hypothesis was supported. Level 3 Infographics were correlated with Similarities \( (r = -0.601, p = 0.001, n = 26) \) and Vocabulary \( (r = -0.515, p = 0.010, n = 24) \). Additionally, significant correlations existed between Level 3 Infographics and the Hooper Visual Organization \( (r = -0.414, p = 0.032, n = 27) \), WASI-II Matrix Reasoning \( (r = -0.282, p = 0.003, n = 112) \), Picture Completion \( (r = 0.440, p = 0.028, n = 25) \). Although not expected, Level 3 Infographics and Graphical Literacy Skills Total were significantly correlated \( (r = -0.321, p = 0.028, n = 47) \).

In sum, we found significant correlations between Level 1 Infographics and WASI-II Matrix Reasoning, WASI-II Similarities, WAIS-III Picture Completion, Benton Judgment of Line Orientation; Level 2 Infographics and the Hooper Visual Organization Test, WASI-II Matrix Reasoning, TMT A, WASI-II Similarities, Graphical Literacy Skills Scale, Graphical B and C subscales; Level 3 Infographics and WASI-II Similarities, WASI-II Vocabulary, the Hooper Visual Organization, WAIS-III Picture Completion Test, WASI-II Matrix Reasoning, Graphical Literacy Skills Scale.

**Comparison of Significant Correlations across the Levels of Processing**

Steiger’s (1980) modification of Dunn and Clark’s \( z \) (1969) statistic was utilized to compare the difference of correlations across the levels of cognitive processing through using a web-based calculator (Diedenhofen & Musch, 2015). The correlation between the Hooper Visual Organization Test and Level 2 Infographics was not significantly different from the correlation between the Hooper Visual Organization Test and Level 3 Infographics \( (z = .0146, p = .988) \). The correlation between WAIS-III Picture Completion Test and Level 1 Infographics was not significantly different from the correlation between WAIS-III Picture Completion Test and Level 3 Infographics \( (z = .0059, p = .995) \). The correlation between WASI-II Similarities and Level 1 Infographics was not significantly different from the correlation between WASI-II Similarities
and Level 2 Infographics ($z = .0644, p = .948$), as well as the correlation between WASI-II Similarities and Level 3 Infographics ($z = 1.2935, p = .195$). The correlation between WASI-II Similarities and Level 2 Infographics was not significantly different from the correlation between WASI-II Similarities and Level 3 Infographics, ($z = .0146, p = .988$). The correlation between WASI-II Matrix Reasoning and Level 1 Infographics and the correlation between WASI-II Matrix Reasoning and Level 2 Infographics were not significantly different from each other ($z = 1.7376, p = .082$). Neither the correlation between WASI-II Matrix Reasoning and Level 1 Infographics and the correlation between WASI-II Matrix Reasoning and Level 3 Infographics ($z = .7471, p = .455$), nor the correlation between WASI-II Matrix Reasoning and Level 2 Infographics and the correlation between WASI-II Matrix Reasoning and Level 3 Infographics were significantly different from each other ($z = -1.0362, p = 0.300$).

In sum, there was no statistically significant difference between correlations between any of the levels of processing and any of the neuropsychological tests.

**Linear Regression Analyses**

In order to understand how much of the variation at each level of cognitive processing was explained by each cognitive function, linear regression analyses were conducted for the variables that displayed statistically significant associations with Infographics.

**Level 1 Infographics.** WASI-II Matrix reasoning significantly predicted Level 1 Infographics, $F(1, 110) = 5.762, p = .018$ and explained 5% of the variability in Level 1 infographics with adjusted $R^2 = 4.1\%$. WASI-II Similarities significantly predicted Level 1 Infographics, $F(1, 24) = 4.64, p = .041$, accounting for 16.2% of the variability in Level 1 Infographics with adjusted $R^2 = 12.7\%$. WAIS-III Picture Completion significantly predicted Level 1 Infographics, $F(1, 23) = 5.552, p = 0.27$ and explained 19.4 % of the variability in Level
Level 2 Infographics. The Hooper Visual Organization significantly predicted Level 2 Infographics, $F(1, 25) = 10.420, p = .003$, accounting for 29.4% of the explained variability in Level 2 Infographics with adjusted $R^2 = 26.6\%$. WASI-II Similarities significantly predicted Level 2 Infographics, $F(1, 24) = 13.405, p = .001$, accounting for 35.8% of the explained variability in Level 2 infographics with adjusted $R^2 = 33.2\%$. Graphical Literacy Skills Scale significantly predicted Level 2 Infographics, $F(1, 45) = 14.389, p < .001$, accounting for 24.2% of the explained variability in Level 2 infographics with adjusted $R^2 = 22.5\%$. TMTA significantly predicted Level 2 Infographics, $F(1, 24) = 4.465, p = .045$ and explained 15.7% of the variability in level 2 infographics with adjusted $R^2 = 12.2\%$. WASI-II Matrix Reasoning significantly predicted Level 2 Infographics, $F(1, 110) = 16.471, p < .001$ and explained 13% of the variability in level 2 infographics with adjusted $R^2 = 12.2\%$. Because Graphical B and Graphical C do not have a linear relationship with Level 2 Infographics, linear regression analyses were not conducted on these variables.

Level 3 Infographics. WASI-II Similarities significantly predicted Level 3 Infographics, $F(1, 24) = 13.569, p = .001$, accounting for 36.1% of the explained variability in Level 3 infographics with adjusted $R^2 = 33.5\%$. WASI-II Vocabulary significantly predicted Level 3 Infographics, $F(1, 22) = 7.941, p = .010$, accounting for 26.5% of the explained variability in Level 3 Infographics with adjusted $R^2 = 23.2\%$. The Hooper Visual Organization Test significantly predicted Level 3 Infographics, $F(1, 25) = 5.172, p = .032$, accounting for 17.1% of the explained variability in Level 3 Infographics with adjusted $R^2 = 13.8\%$. WAIS-III Picture
Completion significantly predicted Level 3 Infographics, \( F(1, 23) = 5.511, p = .028 \), accounting for 19.3% of the explained variability in Level 3 infographics with adjusted \( R^2 = 15.8 \% \). WASI-II Matrix Reasoning significantly predicted Level 3 Infographics, \( F(1, 110) = 9.539, p = .003 \), accounting for 8% of the explained variability in Level 3 infographics scores adjusted \( R^2 = 7.1 \% \).

Graphical Literacy Skills Scale significantly predicted Level 3 Infographics, \( F(1, 45) = 5.186, p = .028 \), accounting for 10.3% of the explained variability in Level 3 infographics with adjusted \( R^2 = 8.3 \% \).

**Multiple Regression Analyses**

In order to understand how much of the variation at each level of cognitive processing was explained by the corresponding neuropsychological tests as a whole, and to examine the unique contribution of each neuropsychological test to explain the variation of each level of cognitive processing, multiple regression analyses were utilized for the variables that displayed statistically significant associations with Infographics. Due to the administration of one of three sets of neuropsychological tests, predictors in each analyses changed accordingly.

**Level 1 Infographics.** Level 1 Infographics was not significantly predicted by WASI-II Similarities, WAIS-III Picture Completion and WASI-II Matrix Reasoning together, \( F(3, 21) = 2.385, p = .098 \). Benton Judgment of Line Orientation Test and WASI-II Matrix Reasoning, together did not explain the variation in Level 1 Infographics, \( F(2, 41) = 2.948, p = .064 \).

Therefore, none of the corresponding neuropsychological tests have a unique contribution to these two models.

**Level 2 Infographics.** Level 2 was significantly predicted by the Hooper Visual Organization Test, TMT A, and WASI-II Matrix Reasoning, together, \( F(3, 20) = 5.155, p = .008 \), with an \( R^2 \) of 43.6, with adjusted \( R^2 = 35.1 \% \). The Hooper Visual Organization Test and
TMTA had unique significant contributions, $p < .05$. Graphical Literacy Scale and WASI-II Matrix Reasoning significantly predicted the variability in Infographics, $F(2, 42) = 7.338, p = .003$, with an $R^2$ of 25.9, with adjusted $R^2 = 22.4\%$. Graphical Literacy Skills Scale had a significant unique contribution to the prediction, $p < .05$.

**Level 3 Infographics.** Level 3 Infographics was not significantly predicted by the Hooper Visual Organization Test and WASI-II Matrix Reasoning, together, $F(2, 24) = 2.760, p = .083$, with an $R^2$ of 18.7, with adjusted $R^2 = 11.9\%$. However, WASI-II Similarities, WASI-II Vocabulary, WAIS-III Picture Completion, and WASI-II Matrix Reasoning significantly predicted Level 3 Infographics, $F(4, 18) = 3.361, p = .032$, with an $R^2$ of 42.8\%, with adjusted $R^2 = 30.0\%$. None of the variables uniquely contributed to the prediction, $p > .05$. Graphical Skills Scale and WASI-II Matrix Reasoning significantly predicted Level 3 Infographics, $F(2, 42) = 3.232, p = .049, R^2 = 13.3$, with adjusted $R^2 = 09.2\%$. However, none of the variables uniquely contributed to the prediction, $p > .05$.

**H3. Cognitive Functions underlying Each Category of Infographics**

**Cognitive Functions Associated with Category of Infographics**

In order to examine the cognitive functions associated with each category of infographics, correlation analyses were conducted between each category of infographics and the corresponding neuropsychological tests (Sanchez-Cubillo et al., 2009).

**Descriptive Statistics for Each Category of Infographics**

There were four different categories of infographics: Data display, maps, timelines, diagrams. Each category of infographics consisted of 9 items (comprised of three examples of each of the level of cognitive processing), for a total of 36 items. The obtained score for each category of infographics was calculated by averaging corresponding test items.
The assumptions for parametric statistics were first tested. Prior to determination of average score for each category of infographics, each test item was examined in terms of normality test. Results indicated that the distribution of each test item was not normally distributed, and therefore data transformation was performed based on the formulae given in Table 4, then each score was converted to a z score. The average z scores were then used in the analyses (see Table 7).

Prior to conducting correlation analyses, descriptive statistics for each category of infographics were determined separately (Table 5). Descriptive statistics were calculated through removing only 1 test item (Level 1 Item 4) based upon the floor effect (Table 7).

**Normality tests for Average Infographics Test Scores for Each Category of Infographics.**

Normality tests were performed based on Fisher skewness coefficient (dividing skewness values to standard errors of skewness) (Kim, 2013) as well as visual inspection of histograms (LaerdStatistics, 2015). Figure 9a, 9b, 9c, and 9d display Data Display, Diagram, Map, and Timeline histograms, respectively.

**Prerequisites for parametric statistics**

Prerequisites for parametric statistics were tested prior to making the decision of whether to use Spearman’s rank-order or Pearson correlation analyses. Only variables that met prerequisites were included in the Pearson correlation analyses.

**Correlation Analyses**

Correlation Analyses were conducted between each category of infographics and corresponding neuropsychological tests (see Table 10a and 10b).

**Data Display.** For cognitive functions associated with Data Display, a significant correlation existed between Data Display Infographics and Graphical Literacy Skills Scale \( r = -\)
.387, \( p = .007, n = 47 \), as expected. The relationship between Data Display and Graphical B and C subscales was not linear. Therefore, Spearman’s rank-order correlation was used, which showed significant correlations (\( r_s = .394, \ p = .006, \ n = 47 \)), and Graphical C subscales (\( r_s = -.309, \ p = 0.034, \ n = 47 \)).

Although not expected, we found significant correlations between Data Display and WASI-II Matrix Reasoning (\( r = -.316, \ p = .001, \ n = 112 \)), the Hooper Visual Organization (\( r = -.428, \ p = .026, \ n = 27 \)), WASI-II Similarities (\( r = -.643, \ p = .000, \ n = 26 \)), WASI-II Vocabulary (\( r = -.444, \ p = .030, \ n = 24 \)), and WAIS-III Picture Completion (\( r = -.529, \ p = .007, \ n = 25 \)).

**Diagram.** For cognitive functions associated with Diagram, a significant correlation existed between Diagram and WASI-II Matrix Reasoning (\( r = -.333, \ p = .000, \ n = 112 \)). Although not predicted, we found significant correlations between Diagram and WASI-II Similarities (\( r = -.494, \ p = .010, \ n = 26 \)), WAIS-III Picture Completion (\( r = -.520, \ p = .008, \ n = 25 \)) and Graphical Skills Scale (\( r = -.314, \ p = .032, \ n = 47 \)).

**Map.** For cognitive functions associated with Map, although a significant correlation was expected between Map and Benton Judgment of Line Orientation Test, results failed to reveal a significant correlation between these variables (\( r = -.146, \ p = .333, \ n = 46 \)). Although not predicted, significant correlations were found between Map and WASI-II Similarities (\( r = -.593, \ p = .001, \ n = 26 \)), WASI-II Vocabulary (\( r = -.439, \ p = .032, \ n = 24 \)), WASI-II Matrix Reasoning (\( r = -.255, \ p = .007, \ n = 112 \)) and Graphical Literacy Skills Scale Total (\( r = -.424, \ p = .003, \ n = 47 \)) based on Pearson correlation results, and Graphical B (\( r = -.340, \ p = .019, \ n = 47 \)), and Graphical C (\( r = -.306, \ p = .037, \ n = 47 \)) based on Spearman rank order correlation results.

**Timeline.** For cognitive functions associated with Timeline, although a significant correlation was expected between Timeline and WMS-III Spatial Span test scores, it was not
found between these two variables \( r = .082, p = .685, n = 27 \). Although not expected, we found a significant correlation between Timeline and WASI-II Similarities \( r = -.426, p = .030, n=26 \), Vocabulary \( r = -.424, p = .039, n = 24 \), and WASI-II Matrix Reasoning \( r = -.230, p = .015, n = 112 \). The correlation between Timeline and TMTA approached significance, \( r = -.383, p = .054, n = 26 \).

In sum, we found significant correlations between Data Display and Graphical Literacy Skills Scale, Graphical B and C subscales, WASI-II Matrix Reasoning, the Hooper Visual Organization Test, WASI-II Similarities, WASI-II Vocabulary and WAIS-III Picture Completion; Diagram and WASI-II Matrix Reasoning, WASI-II Similarities, WAIS-III Picture Completion, and Graphical Literacy Skills Scale; Maps and WASI-II Similarities, WASI-II Vocabulary, WASI-II Matrix Reasoning and Graphical Literacy Skills Scale, Graphical B and C subscales; Timeline and WASI-II Similarities, WASI-II Vocabulary and WASI-II Matrix Reasoning.

**Comparison of Significant Correlations across the Categories of Infographics**

Steiger’s (1980) modification of Dunn and Clark’s \( z \) (1969) was utilized to compare the difference of correlations across the categories of infographics through using a web-based calculator (Diedenhofen & Musch, 2015). The correlation between WASI-II Similarities and Data Display and the correlation between WASI-II Similarities and Diagram were not significantly different from each other \( z = -.0914, p = .9272 \), The correlation between WASI-II Similarities and Data Display and the correlation between WASI-II Similarities and Map were not statistically significantly different from each other \( z = -.0702, p = .9441 \). The correlation between WASI-II Similarities and Data Display and the correlation between WASI-II Similarities and Timeline were not significantly different from each other \( z = -1.4297, p = \)
0.1528). The correlation between WASI-II Similarities and Diagram, and WASI-II Similarities and Map were not significantly different from each other ($z = 0.0424, p = 0.9662$). The correlation between WASI-II Similarities and Diagram and the correlation between WASI-II Similarities and Timeline ($z = -1.5397, p = .1236$) as well as the correlation between WASI-II Similarities and Map and the correlation between WASI-II Similarities and Timeline were not significant from each other ($z = -1.7634, p = .0778$). There was no statistically significant difference between the correlation between WASI-II Vocabulary and Data Display and the correlation between WASI-II Vocabulary and Map ($z = -.636, p = .9493$), the correlation between WASI-II Vocabulary and Data Display, and the correlation between WASI-II Vocabulary and Map ($z = -.2145, p = .8301$), the correlation between WASI-II Vocabulary and Data Display and the correlation between WASI-II Vocabulary and Timeline ($z = -.2145, p = .8301$), the correlation between WASI-II Vocabulary and Map and the correlation between WASI-II Vocabulary and Timeline ($z =-.3902, p = .6964$). No statistically significant difference was found between the correlation between WAIS-III Picture Completion and Data Display and the correlation between WAIS-III Picture Completion and Diagram ($z = -.0661, p = .9473$). No statistically significant was found between the correlation between Graphical Skills Scale and Data Display and the correlation between Graphical Skills Scale and Diagram ($z = -.4051, p = .6854$), the correlation between Graphical Skills Scale and Data Display and the correlation between Graphical Skills Scale and Map ($z = -5873, p = .5570$), the correlation between Graphical Skills Scale and Diagram and the correlation between Graphical Skills Scale and Map ($z = -.1672, p = .8672$). No statistically significant difference was found between the correlation between WASI-II Matrix Reasoning and Data Display and the correlation between WASI-II Matrix Reasoning and Diagram ($z = .1458, p = .8841$), the correlation between WASI-II Matrix
Reasoning and Data Display and the correlation between WASI-II Matrix Reasoning and Map ($z = .1458, p = .8841$), the correlation between WASI-II Matrix Reasoning and Data Display and the correlation between WASI-II Matrix Reasoning and Timeline ($z = -1.4080, p = 0.1591$), the correlation between WASI-II Matrix Reasoning and Diagram and the correlation between WASI-II Matrix Reasoning and Map ($z = -.4971, p = .6191$), the correlation between WASI-II Matrix Reasoning and Diagram and the correlation between Matrix Reasoning and Timeline ($z = -1.8831, p = .0597$), the correlation between Matrix Reasoning and Map and the correlation between WASI-II Matrix Reasoning and Timeline ($z = -1.0130, p = .3110$).

In sum, no statistically significant difference was found among correlations between categories of Infographics and neuropsychological tests.

**Linear Regression Analyses**

In order to understand how much of the variation at each category of infographics was explained by each cognitive function, we conducted linear regression analyses on the variables that displayed significant associations with Infographics.

**Data Display.** Graphical Literacy Skills Scale significantly predicted Data Display, $F(1, 45) = 7.907, p = .007$, accounting for 14.9% of the explained variability in Data display with adjusted $R^2 = 13.1%$. WASI-II Matrix Reasoning significantly predicted Data Display, $F(1, 110) = 12.236, p = .001$ and explained 10% of the variability in Data Display with adjusted $R^2 = 09.2%$. The Hooper Visual Organization Test significantly predicted Data Display, $F (1, 25) = 5.617, p = .026$ and explained 18.3% of the variability in Data Display with adjusted $R^2 = 15.1%$. WASI-II Similarities significantly predicted Data Display, $F (1, 24) = 16.899, p<.001$, accounting for 41.3% of the explained variability in Data Display with adjusted $R^2 = 38.9%$. WASI-II Vocabulary significantly predicted Data Display, $F (1, 22) = 5.415, p = .030$,
accounting for 19.8% of the explained variability in Data Display with adjusted $R^2 = 16.1\%$.

WAIS-III Picture Completion significantly predicted Data Display, $F(1, 23) = 8.956$, $p = .007$, accounting for 28% of the explained variability in Data Display with adjusted $R^2 = 24.9\%$.

**Diagram.** WASI-II Matrix Reasoning significantly predicted Diagram, $F(1, 110) = 13.391$, $p < .001$, accounting for 11.1% of the explained variability in Diagram with adjusted $R^2 = 10.3\%$. WAIS-III Picture Completion significantly predicted Diagram, $F(1, 23) = 8.531$, $p = .008$, accounting for 27.1% of the explained variability in Diagram with adjusted $R^2 = 23.9\%$.

WASI-II Similarities significantly predicted Diagram, $F(1, 24) = 7.751$, $p = .010$, accounting for 24.4% of the explained variability in Diagram with adjusted $R^2 = 21.3\%$. Graphical Literacy Skills Scale significantly predicted Diagram, $F(1, 45) = 4.912$, $p = .032$, accounting for 9.8% of the explained variability in Diagram with adjusted $R^2 = 7.8\%$.

**Map.** WASI-II Similarities significantly predicted Map, $F(1, 24) = 12.996$, $p = .00$, accounting for 35.1% of the explained variability in Map with adjusted $R^2 = 32.4\%$. WASI-II Vocabulary significantly predicted Map, $F(1, 22) = 5.262$, $p = .032$, accounting for 19.3% of the explained variability in Map with adjusted $R^2 = 15.6\%$. WASI-II Matrix Reasoning significantly predicted Map, $F(1, 110) = 7.623$, $p = .007$, accounting for 06.5% of the explained variability in Map with adjusted $R^2 = 05.6\%$. Graphical Literacy Skills Scale significantly predicted Map, $F(1, 45) = 9.851$, $p = .003$, accounting for 18% of the explained variability in Map with adjusted $R^2 = 16.1\%$.

**Timeline.** Similarities significantly predicted Timeline, $F(1, 24) = 5.309$, $p = .030$, accounting for 18.1% of the explained variability in Timeline with adjusted $R^2 = 14.7\%$. WASI-II Vocabulary significantly predicted Timeline, $F(1, 22) = 4.835$, $p = .039$, accounting for 18% of the explained variability in Timeline with adjusted $R^2 = 14.3\%$. WASI-II Matrix Reasoning
significantly predicted Timeline, $F(1, 110) = 6.117$, $p = .015$, accounting for 5.3% of the explained variability in Timeline with adjusted $R^2 = 4.4\%$.

**Multiple Regression Analyses**

In order to understand how much of the variation at each category of infographics was explained by the corresponding neuropsychological tests together, and to examine the unique contribution of each neuropsychological test to explain the variation of each category of infographics, multiple regression analyses were utilized for the variables that displayed statistically significant associations with Infographics. Due to the administration of one of three sets of neuropsychological tests, predictors in each analyses changed accordingly.

**Data Display.** In multiple regression analyses, the Hooper Visual Organization Test and WASI-II Matrix Reasoning together did not statistically significantly predict Data Display, $F(2, 24) = 2.996$, $p = .071$ and explained 19.8% of the variability in Data Display with adjusted $R^2 = 13.1\%$. However, WASI-II Similarities, WAIS-III Picture Completion, WASI-II Vocabulary, and WASI-II Matrix Reasoning together significantly predicted Data Display, $F(4, 18) = 4.464$, $p = .011$ and explained 49.8% of the variability in Data Display with adjusted $R^2 = 38.6\%$. Similarities significantly contributed to the prediction, $p < .05$. Graphical Skills Scale and Matrix Reasoning together significantly predicted Data Display, $F(2, 42) = 4.269$, $p = .021$ and explained 16.9% of the variability in Data Display with adjusted $R^2 = 12.9\%$.

**Diagram.** WASI-II Similarities, WAIS-III Picture Completion, WASI-II Matrix Reasoning together, significantly predicted Diagram, $F(3, 21) = 3.779$, $p = .026$, and explained 35.1% of the variability in Diagram with adjusted $R^2 = 25.8\%$. Similarities significantly contributed to the prediction, $p < .05$. Graphical Skills Scale and WASI-II Matrix Reasoning
significantly predicted Diagram, $F (2, 42) = 3.390$, $p = .043$, and explained 13.9% of the variability in Diagram with adjusted $R^2 = 09.8$.

**Map.** The multiple regression model was statistically significantly predicted Map, $F(3,20) = 3.857$, $p = .025$, and explained 36.7% of the variability in Map with adjusted $R^2 = 27.1$. Similarities contributed statistically significance to the prediction, $p = .037$. The multiple regression model was statistically significantly predicted Map, $F(2,42) = 4.663$, $p = .015$, and explained 18.2% of the variability in Map with adjusted $R^2 = 14.3$. Graphical Skills Scale contributed statistically significance to the prediction, $p = .019$.

**Timeline.** The multiple regression model was not statistically significantly predicted Timeline Infographics scores, $F(3,20) = 1.941$, $p = .156$ and explained 22.5% of the variability in Timeline with adjusted $R^2 = 10.9$. None of the variables contributed statistically significance to the prediction.

**Correlation Analyses among the Neuropsychological Tests**

Pearson correlation analyses were utilized in order to determine the associations among the neuropsychological tests. Because a different set of neuropsychological tests was administered for each hypothesis, the neuropsychological tests included in the correlation analyses changed accordingly. Because z scores of neuropsychological test scores were included in the correlation analyses for each hypothesis, the same data set was utilized in the correlation analyses.

We found significant correlations between Navon Global and Navon Local ($r = .849$, $p<.001$, $n=25$), Navon Local and TMT B ($r = .534$, $p = .013$, $n = 21$), the Hooper Visual Organization Test and WASI-II Block Design ($r = .577$, $p = .002$, $n = 26$), WASI-II Matrix Reasoning and WASI-II Block Design ($r = .659$, $p<.001$, $n = 28$), the Hooper Visual
Organization Test and WASI-II Matrix Reasoning ($r = .492, p = .009, n = 27$), TMT-A and TMT-B ($r = .440, p = .040, n = 22$).

We also found significant correlations between WASI-II Vocabulary and WASI-II Similarities ($r = .603, p = .002, n = 24$), WAIS-III Picture Completion Test and WASI-II Similarities ($r = .480, p = .015, n = 25$), WASI-II Matrix Reasoning and WASI-II Similarities ($r = .527, p = .006, n = 26$), WASI-II Matrix Reasoning and WAIS-III Picture Completion Test ($r = .555, p = .004, n = 25$).

We found significant correlations between Judgment of Line Orientation test and WASI-II Matrix Reasoning ($r = .309, p = .041, n = 44$), WASI-II Matrix Reasoning and Graphical Literacy Skills Scale ($r = .507, p < .001, n = 45$).

**Chapter 4: Discussion**

Context processing deficits can be seen in several clinical populations such as patients with schizophrenia (Phillips & Silverstein, 2003; Phillips & Singer, 1997). To date context processing and related cognitive functions deficits were identified through the administration of several neuropsychological tests (e.g., Cohen & Servan-Schreiber, 1992; Servan-Schreiber et al. 1996) and tasks (see for a review Silverstein & Keane, 2011). Each neuropsychological test taps into various perceptual or cognitive functions (e.g., Cohen & Servan-Schreiber, 1992). In the related studies context was described based upon cognitive functions (e.g., Cohen & Servan-Schreiber, 1992) or corresponding levels of processing (e.g., perceptual level) (Park et al., 2003). However, no standardized test has been developed to assess context processing as global processing through comparison. The current project sought to develop a novel test to evaluate context processing based upon global processing through comparison of visual images. Because understanding context in Infographics (information graphics) requires “to compare” visual
features (Tufte, 1983) and global information processing, Infographics were developed based upon the visualization design principles. The process was comprised of two phases: Phase 1 consisted of the process of test development, Phase 2 consisted of testing the validity and reliability of the newly developed test items.

**Test Item Development and Pilot Testing**

Prior to testing validity and reliability of the tests, the pilot phase proceeded in three steps. Because each test item was made up of task relevant features, task-irrelevant features (red herrings), and a question that required to find the consistency among the visual features, addressing the source of the changes was challenging. Test items contained pictograms, abstract images, and text that were incorporated in task-relevant and task-irrelevant features. Following an iterative process in each step, some of the test items were modified, some of them were removed, and new ones were added.

Some of the abstract images (e.g., circles) were not comprehended by participants. Therefore, they were replaced by the corresponding icons (e.g., Level 2 Item 12). Although both pictograms and abstract graphics represent either quantitative or qualitative entity, due to their figurative formats, pictograms may be comprehended more easily. Some of the pictograms in test items were not comprehended and in the subsequent pilot study, the corresponding words were added to clarify them (e.g., Level 2 Item 4). Pictograms are affected by familiarity (Tijus, et al., 2007), and therefore participants who may not be familiar with the icons may need additional information to comprehend the images.

Across the pilot studies, the questions were carefully examined in terms of clarifying the task-relevant information. Some questions were not clear enough to address the task-relevant features. For instance, initially Level 1 Item 1 that contained the question “What causes the
circle to get darker?" did not enable most of the participants to answer the question correctly. The word “what” indicated a broad concept. Participants did not comprehend what parts they needed to search for the answer in the test item. Therefore, the question was changed as follows: “How does one of these shapes cause the circle to get darker?” This question enabled the participants to compare the color of the circles and the size of triangles and answer the question. After this change, the number of correct answers for this specific item increased. The perceptual tasks reviewed by Shah et al. (2005), and integrative information extraction theory proposed by Ratwani et al. (2008), focused on extracting information through asking basic questions that facilitate finding answers through pattern recognition, such as differentiating values of visual variables. Questions should be clear to guide participants’ visual processing.

During the implementation of the pilot studies, the questions, consistent changes of task-relevant features, and random changes of task irrelevant features, were not sufficient to visually guide participants to the correct answer. In addition to visual guidance, verbal queries and prompts were needed to accommodate them to respond the questions correctly. As used in WAIS-III Picture Completion (Wechsler, 1997b), WASI-II Similarities and WASI-II Vocabulary (Wechsler, 2011), prompts and queries were utilized as verbal aids to provide the correct responses. In this test, due to insufficient guidance of a single prompt, multiple queries and prompts were prepared for each component (task relevant, task irrelevant, or questions). Although this process facilitates participants’ comprehension, it requires more attentiveness by the experimenter to follow each response along with the visual display, while providing the appropriate prompts and queries.

As provided in most of the neuropsychological tests, such as WASI-II Matrix Reasoning, WASI-II Similarities, WASI-II Vocabulary (Wechsler, 1997b, 2011), four practice questions
were provided to ensure the comprehension on instructions and tasks. Based on the pilot studies, providing instructions along with the practice questions was found more effective than providing the instructions alone.

During the pilot study, across levels of difficulty, each visual variable and icon were adjusted by means of numerical values given in Adobe Illustrator CC. After numerous iterations of the test items, in validity testing additional adjustments were required. Each iteration meant the test items would be used in the subsequent trial. Therefore, the scores related to these values (31 data scores) were removed from the data set.

**Test Items Difficulty**

**Ceiling and Floor Effects**

In the literature there are mixed conclusions as to whether ceiling effects should be calculated based upon the top 15 % (Lim et al., 2015), 10%, 20%, 40 % (Resch & Isenberg, 2018) or 29 % (Dean et al., 2018) or whether floor effects should be calculated based upon bottom 15 % (Lim et al., 2015) of participants’ responses.

Test item errors belong mostly to Diagram, such as Level 1 Item 4, Level 1 Item 6, Level 2 Item 12. For instance, Level 1 Item 4 consisted of arrows and numbers. Increasing the thickness of task-relevant arrows served as task relevant features. Changing the numbers served as task irrelevant features. Many of the participants may not be able to respond this question correctly due to several reasons: (1) The answer indicated basic calculations between the numbers. Some participants may not have been able to make the connection between basic calculations and the size of arrow due to the limited working memory capacity (Kosslyn, 1994). (2) Arrow as context-dependent objects (Malamed, 2009; Tversky, 2011) may have provided ambiguous cues. Because this item belonged to Level 1-low level processing, arrows may not
benefit from the context. Level 1 Item 6 was a hierarchical node-link diagram consisting of red boxes and other color boxes. As Triesman (1985) discussed parallel processing and serial processing on pre-attentive features, intentionally in this item visual variables that would facilitate parallel processing were avoided to encourage participants to compare each part. Displaying excessive number of boxes to compare may reduce performance in working memory (Kosslyn, 1994). Although sufficient contrast was settled between the number of red boxes and other boxes, gradually increasing visual salience of red boxes may not be sufficient to enable participants to respond the answer correctly.

Level 2 Item 12 was also a diagram that marks such as lines represented how many soccer balls two teams shared. Decreasing size of the triangle when two teams share were task relevant features, changing color of the triangles were task-irrelevant features, changing location of the different size of triangles were used to avoid local processing. Different sizes of triangles were labeled as a legend. Line comprehension required understanding context (Tversky, 2011). Because sharing the balls were determined by the number of lines, and the lines were not clarified as a legend, some of the participants may not have been able to make a connection between the abstract meaning of lines.

Two test items that were not answered correctly in more than 20% of participants belonged to Timeline. In this study, the timelines were structurally different from each other. For instance, in Level 2 Item 3, length of lines represented time spent. Although there was a legend that explained what each line meant (e.g., short line represents short time), it was still hard for the readers to comprehend the connection between the lines and the time spent. Spatial gap in timelines is figurative (Malamed, 2009; Tversky, 2011). If the viewers are not familiar with this connection (Shah et al., 2005), it may be harder for them to respond the answer correctly. This
test item consisted of the icons without words. These icons might serve as “chartjunks” (Tufte, 1983) and might distract participants to focus on the task relevant features. Too many distractors may increase working memory load. Level 3 Item 3 was another type of Timeline that was not responded to correctly by some participants. Although the structure of the design was like a clock, and midnight and morning served as an indicator of time, two reasons may explain the difficulty of this test item: (1) the icons were represented without words. Because understanding “pictograms” required familiarity (Tijus et al., 2007), some participants may not be familiar with the icons. Although in this test item the icons resembled the actual objects to avoid the familiarity effect, the connection between the items and time represented were still vague for some participants. (2) As Tversky (2011) proposed, circles may be difficult to perceive as a timeline rather than a linear pattern due to not displaying progressive changes on a horizontal line. Participants may seek some clues that represent starting of a day to perceive an abstract shape as a timeline (Tversky, 2011).

There were also some items that were easily answered correctly. For instance, Level 1 Item 9 contained more than one task-relevant visual cue that can enable Perceptual Organization (similarity) to facilitate perceptual processing. Level 1 Item 8 consisting of patterns of dots enabled participants to compare one row with other rows easily. Spatial position, which is the highest ranked visual variable based on principle of effectiveness (Bertin, 1983; Munzner, 2015), or pattern recognition based on the shapes of dots, may facilitate the process rather than counting the number of dots. Taken together, these effects suggest that although design principles are crucial to develop the test items, participants should be involved in the development process of the tests items.

Hypothesis 1
In this study, context was operationalized as global processing through comparison of images. In accordance with this definition, as expected, significant correlations existed between Infographics and the Hooper Visual Organization Test, WASI-II Matrix Reasoning, and WAIS-III Picture Completion Test. No significant correlation occurred between Infographics and WASI-II Block Design and Navon Local processing scores. Unexpectedly, WASI-II Similarities, WASI-II Vocabulary, and Graphical Literacy Skills Scale were also correlated with Infographics.

In order to investigate how much of the variation in Infographics can be explained by each neuropsychological test individually and together, as well as how much each test uniquely contribute to prediction, linear and multiple regression analyses were conducted. Results of linear regression analyses showed that the Hooper Visual Organization Test and WASI-II Vocabulary accounted for similar percentages of the variability in Infographics. Surprisingly, highest and lowest percentages of the variation in Infographics were explained by WASI-II Similarities and WASI-II Matrix Reasoning, respectively.

Although one operational definition of context was identified, there have been different approaches to operational definitions (Franzen, Robbin, & Sawicki, 1989). Fiske (1976) suggested the incorporation of the methods into construct definition. Franzen et al. (1989) proposed three facets of behavior that may contribute to this matter: Stimulus modality (e.g., visual memory), processing during the implementation of the test (e.g., visual encoding vs. verbal encoding), and response (e.g., verbal vs. writing). In accordance with the administration of the Infographics test, these three facets may be defined as follows: stimulus (comparison and global processing), processing (verbal reasoning), and response (verbal response through the use
of words). Although these facets may not explain the results of correlation and regression analyses, they may enable to question the unexpected results.

The ambiguity of cognitive functions targeted in context processing may initiate a discussion between “what to measure” and “how to measure”. For instance, Hooper Visual Organization, which was found to significantly correlated with Infographics, measures visual organization (what to measure) through object naming (how to measure). It is crucial to note that a small percentage of object naming contributed to the variation in the Hooper Visual Organization Test (Rickel & Axelrod, 1995). Based upon the results of linear regression analyses in the current study, it was found that WASI-II Vocabulary and the Hooper Visual Organization explained almost the same percentage of the variability in Infographics when each variable was included into analyses separately. Because these two tests were not administered to the same participants, they were not included together in the multiple regression analyses. Therefore, it is not clear relatively how much they contribute to the prediction. Because each test item contained verbal questions and required visual organization of the visual variables, both results may contribute separately to define the construct.

Context processing is related to perceptual organization (Phillips & Silverstein, 2003) and global processing (Ben-Yosef et al., 2017; Torralba et al., 2006). As the Hooper Visual Organization Test was significantly correlated to Infographics, in terms of the facets of behavior proposed by Franzen et al. (1989), the stimulus may target visual organization. Phillips and Silverstein (2003) proposed that context is grouping local features to make a meaningful entity that enables global integration of higher order representations. In this respect, low level perceptual organization (perceptual level) and high level (conceptual level) (Phillips & Silverstein, 2003) may both contribute to Infographics test items. WAIS-III Picture Completion,
which is significantly correlated with Infographics, required participants to pay attention to the
details and understand context by global processing (Van clef, nd.). On the other hand, Navon
Global Precedence, which was used to test global precedence, did not correlate to Infographics.
According to global precedence hypothesis, Gestalt principles such as proximity and similarity
play a crucial role in processing global features first, compared to processing local features
(Kimchi, 1992; Navon, 1977). In order to test this hypothesis, global level letters (letter in large
size) made up of local level letters (letter in small size) were presented to participants who were
expected to ignore local level letters, and to notice global level letters quickly. Local level letters
do not convey any meaning in processing global level letters. Unlike Navon Global precedence,
Infographics test items required global processing by paying attention to local features (focusing
on task-relevant features and inhibiting task-irrelevant features), similar to requirements of
WAIS-III Picture Completion. Therefore, the results may show that global processing via
involving or ignoring local features may trigger different mechanisms. In addition, in
Infographics, meaningful local features may contribute to global processing as seen in Picture
Completion Test.

Unlike visual reasoning measured by WASI-II Matrix Reasoning, verbal abstract
reasoning measured by Similarities explained higher variation in Infographics when each test
was included in the linear regression analyses separately. When they were included together as a
predictor in the multiple regression analyses, they significantly predicted Infographics. However,
each test did not uniquely contribute to this prediction. Both cognitive processing indicate
abstract reasoning with different sensory modalities. Ratwani et al. (2008) proposed that visual
integration can be based on mutual features that visual variables share (e.g., size), or semantic
categories to which they belong. WASI-II Similarities is required to find the similarities between
two words (Wechsler, 2011). Both visual and verbal processes may require comparison. However, it is not clear whether this comparison may tap into the same cognitive function. The Dual Coding Theory that explains how verbal and non-verbal entities are processed independently at the same time (Paivio, 1986) and play a crucial role in memory may also emphasize how visual patterns on the infographics be processed visually and verbally in the meantime.

As expected, Navon Local Processing and WASI-II Block Design were not correlated to Infographics. Although in this study, WASI-II Block Design has been accepted as a local processing test (Drake et al., 2010; Drake & Winner, 2011), it measures abstract spatial perception (Wechsler, 2011) and does not clearly indicate an individual cognitive function. Therefore, it is not clear if Infographics are not related to spatial perception or local processing.

Because the subtests of intelligence test were administered as cognitive tests in this study, the total intelligence test score was not identified as a separate score. Intelligence may influence both factors.

Graphical Literacy Skills Scale was initially expected to be correlated with only one type of abstract graphics which is data display. However, the term “graphics” may comprise various abstract graphics maps, data display, diagram, and timeline (Malamed, 2009; Ratwani et al., 2008; Tversky, 2011). The infographics total score was measured based on the average of all infographics and levels of difficulty varied depending on quantitative changes. Because Graphical Skills Scale measures quantitative information, incorporating quantitative features into each test item may contribute to this association. Not only visual features of test items (Shah, et al., 2005) but also, knowing how to read the components of the graphs indicated by Pinker (1990) as “graph schema”, may play a prominent role in responding the questions in
Infographics. Graphical Literacy Skills Scale contained questions that required extracting information from graphs, associating data points to each other and reasoning beyond data (Galesic & Garcia-Ratamero, 2011). Therefore, participants who were able to comprehend graphs performed well on Infographics as well.

In sum, context was pre-identified as global processing through comparison of visual images. Cognitive functions underlying context processing partially supported our hypothesis that Infographics was significantly associated with the Hooper Visual Organization and WAIS-III Picture Completion, but not Navon Global Precedence. Global precedence may be different from “global processing” mentioned in this study in terms of meaningfully contributions of local features to this process. In addition, results showed that there may be different facets of behavior measured by a test that may target different cognitive functions, such as WASI-II Similarities and WASI-II Vocabulary. Unlike WASI-II Matrix Reasoning, WASI-II Similarities, as a measure of verbal reasoning, accounted for a high percentage of variability in Infographics in linear regression analyses. In the multiple regression analyses, WASI-II Similarities, WASI-II Matrix Reasoning were included along with WASI-II Vocabulary, and WAIS-III Picture Completion Test. Although overall prediction was significant, none of the variables did significantly contribute to the prediction. The unique contribution of each test to the prediction is not clear.

Hypothesis 2

We hypothesized that the three levels of cognitive processing would require specific cognitive functions. Although Similarities was only expected to be correlated with Level 3, all levels of cognitive functions were correlated with Similarities. All three levels may require
verbal abstract reasoning. Because intelligence was not measured in the administration of Infographics, it is not clear that if it can serve as a confound in this matter.

Level 1 contained visual variables such as size, shape, and color that enable pattern recognition. WASI-II Matrix Reasoning was significantly low correlated with Level 1, also explained very little variability in Level 1 in linear regression analysis. Unlike WASI-II Matrix Reasoning, WAIS-III Picture Completion accounted for higher percentage of variability in Infographics in linear regression analysis. Global processing by paying attention to the details and understanding context may require low level perceptual organization that Level 1 can be associated with. Because when both variables were included in multiple regression analyses, the relative contribution of each test was insignificant, thereby it is still not clear whether the contribution of WAIS-III Picture Completion test was higher.

Benton Judgment of Line Orientation and WASI-II Matrix Reasoning had low correlations with Infographics. Benton Judgment of Line Orientation measures spatial perception and spatial orientation without requesting any problem solving ability. WASI-II Matrix Reasoning requires spatial perception along with problem solving abilities. When both variables are included into multiple regression analyses, the result was not significant. Although Benton Judgment of Line Orientation explained slightly higher percentage (not a drastic change) of variation in Infographics than WASI-II Matrix Reasoning, due to the low correlations, it may not be concluded that Level 1 is associated with spatial perception, but not strongly with problem solving.

Level 2 items were constructed based on pictograms (e.g., icons in Item 4) or visual variables (e.g., visual variables with words given in the legend in Item 10). Participants were required to comprehend the patterns through comparison and make an integration of abstract
images to quantitative information and then to the real-world images to make a meaningful entity. The information processing followed in Level 2 may correspond to the tasks held, with respect to the integrative information extraction theory (Ratwani et al., 2008) in addition to those held in the tasks that require to understand how to read a graph and how to make connections with the corresponding real-world images (Bertin, 1983; Shah et al., 2005). Pinker (1990) focused on the importance of knowledge of viewers on understanding graphs, limited cognitive capacities of viewers, and visual characteristics during this process. Carpenter and Shah (1998) added the repetitive processing to this single process. Ratwani et al. (2008) emphasized visual aspect through combining visual variables based upon the mutual features that they share, and cognitive aspect through comparison of grouped variables in addition to repetitive process, in order to encourage integrative information processing. Significant correlation between Infographics and the Hooper Visual Organization, which requires integrating pieces of an object, may be an indicator of the underlying integrative information processing.

Interestingly, WASI-II Matrix reasoning explained higher percentages of variability in Level 2 than in Level 1 based on linear regression analysis. However, Steiger’s (1980) modification of Dunn and Clark’s z (1969) statistic did not show any significant difference between the correlation between WASI-II Matrix Reasoning and Level 1, and the correlation between WASI-II Matrix Reasoning and Level 2. Level 1 required comparison of the visual variables (perceptual level) whereas, Level 2 required making connections with real-world applications, in addition to pattern recognition. Because WASI-II Matrix Reasoning measures more than one cognitive function, such as problem solving, pattern recognition, or visual abstract reasoning (Wechsler, 2011), specifying cognitive functions for Level 2 may be challenging. Level 2 may correspond to connecting visual variables to quantitative information and making
connections with real-word application (Bertin, 1983; Pinker, 1990; Ratwani et al., 2008; Shah et al., 2005) of understanding graphs, where additional spatial elements and comparison of grouped elements were proposed to explain the integrative information extraction theory (Ratwani et al., 2008), Matrix Reasoning may explain the percentage of variation in one these stages of Infographics. In addition, Graphical Literacy Scale, which were significantly correlated with Level 2, did not correlate to Level 1. This association may indicate that the questions in Graphical Literacy Scale may measure similar functions as Level 2.

Unlike Level 1, Level 2 consists of Pictograms that are comprehended within context (Tijus et al., 2007). Within Level 2, specifying the source of context processing may be challenging in this case. Connecting pictograms with their referents may facilitate the visual organization process.

Categorization in Level 3 was based upon grouping two or three visual variables or icons with each other and differentiating them on the basis of perceptual comparison. Items consist of the visual variables (e.g., Item 8), icons presented either without words (e.g., Item 3), with words (e.g., Item 5), or with words in a legend (e.g., Item 4). Answering the questions of these test items required comparing visual variables (e.g., thickness of lines or size of circles), then categorizing icons based on saliency of task-relevant items. When included Similarities along with other neuropsychological tests into multiple regression analyses, although there was an overall prediction, there was no significant unique contribution of neuropsychological tests. Similarities accounted for higher percentage of variability in Level 3 in linear regression, this result may raise interesting questions on categorization. Perceptual integration may have occurred through grouping the visual variables with mutual perceptual features or semantic categories. Cognitive integration may have occurred through comparing the groups of visual
variables or icons to those with opposite features as Ratwani et al. (2008) proposed in integrative information theory. Therefore, Level 3 may indicate both perceptual and cognitive integration. Both WASI-II Similarities and Level 3 required taxonomic categorization based on semantic memory (Rozencwajg, 2007). Additionally, icons and words were either concrete (e.g., Item 3) or abstract (e.g., Item 8). As Paivio (1971) explained verbal processing may assist in memorizing abstract words, however, dual coding may be required for concrete words. Because the Level 3 score was calculated by averaging all Level 3 test items, it is not clear if this part related to verbal reasoning or double coding. Although memory was not one of the primary cognitive functions in Level 3, verbal processing may have facilitated the process.

Similarities and Vocabulary explained a higher percentage of variation in Infographics, compared to Graphical Literacy Skills Scale and WASI-II Matrix Reasoning when taken separately in linear regression analyses. However, Level 3 may require verbal reasoning rather than visual reasoning and understanding graphs. Visual abstract reasoning and verbal abstract reasoning may be different cognitive functions. Visual abstract graphics can be a tool for visual abstract reasoning and can incorporate visual variables, such as length or size. Verbal abstract reasoning can be processed through defining abstract features of both concrete and abstract words.

To sum up, Level 1 Infographics are weakly correlated with WASI-II Matrix Reasoning and Benton Judgment Line Orientation. Unlike Level 1 Infographics, Level 2 were moderately correlated with Matrix Reasoning and Hooper Visual Organization. Similarities and Vocabulary explained a higher percentages of variability in Level 3 compared to Matrix Reasoning. Level 3 may require verbal reasoning rather than visual reasoning.

**Hypothesis 3**
Cognitive domains underlying each infographic was expected to be different. The results did not show clear distinctions among the categories of infographics.

Based on previous empirical studies (for a review see Tversky, 2005, 2011), maps convey real-world reflected spatial relations, whereas timeline or data display (e.g., bar charts) convey figurative spatial relations. Judgment of Line Orientation reflects spatial perception, spatial orientation, and visuospatial processing. Because significant correlations were not found between Judgment of Line Orientation and any category of infographics, it is not clear whether visual-spatial processing underlying this test is related to real-world based or figurative spatial relations.

Items in the same category may or may not be perceptually similar to each other (Lohse et al., 1994). For instance, there were different types of maps, including cartographs such as dot maps, choropleths that contain quantitative information. However, the items within the Map category contain the same features (e.g., spatial regions). In Diagram, Level 2 Item 7 and Level 2 Item 12 were not visually similar to each other. Although Diagrams contained qualitative information, in order to create the levels of difficulty, various quantitative changes were implemented. For instance, Level 3 Item 2 varied based upon the number of icons. However, Level 2 Item 7 has changed based on the size of circles as well as the number of the corresponding lines. The structure of the test items and the levels of difficulty may explain the reason of significant correlations between Graphical Skills Scale and Data Display, Diagram, and Map. Although no significant differences were identified between the correlational analyses between Graphical Skills Scale and aforementioned categories of Infographics, this scale explained higher percentages of the variability in Data Display and Maps than Diagram when separately analyzed in linear regression analyses. Graphical Skills Scale contained bar charts, line charts, and required interpretations of the graphs in different levels. Specifically, Data
Display also required associating different data points to each other, and reasoning beyond given data. Therefore, participants may convey these skills to respond Data Display items correctly. Because thematic Maps were also utilized in this study, quantitative information overlapped with spatial regions. Therefore, understanding Maps also may require graphical skills.

In Timeline Infographics, items displayed time not always structurally similar to each other. For instance, Level 3 Item 2 is not visually similar to Level 3 Item 3, whereas, it is visually similar to Level 1 Item 10. However, both items contained temporal entities. Temporal entities usually convey sequential information (Malamed, 2009; Tversky, 2011) that may enable spatial working memory. However, significant correlations did not exist. Timelines are usually displayed as horizontal lines (Tversky, 2011). Tversky (2011) indicated that perceiving increase of time on a horizontal line depends on participants’ writing and reading patterns. In this study, Level 1 Item 10, Item 11, Item 12 were abstract images belong to Timeline. Although Item 10 and 11 were required to find consistency in the images and both answers were accepted (e.g., from left to right or from right to left), Item 12 was required to find the decrease from left to right. Some participants may have had difficulty in perceiving this pattern. Surprisingly, correlation between Trail Making Test A and Timeline was closer to significance. Although Trail Making Test A was administered to test attention, the administration of the test include following the numbers sequentially. Cognitive functions underlying connecting numbers sequentially may address timelines.

Unlike Maps and Timelines, Data Display and Diagrams were correlated to WAIS-III Picture Completion Test. Data Display and Diagram may convey global processing features through paying attention to meaningful local features. Data Display is also correlated to the
Hooper Visual Organization Test. Data Display may convey both visual organization and global processing features.

In sum, WASI-II Similarities were correlated with all categories of infographics. Not only Data Display but also Diagrams and Maps were also correlated with Graphical Skills Scale. As the terms “graphics”, “diagrams”, or “charts” have mixed definitions in the literature (Börner et al., 2019; Kosslyn, 1994; Ratwani et al., 2008; Shah et al., 2005; Ware, 2012) and levels of difficulty varied depending on the quantitative information, graphical literacy skills may correspond to other abstract graphics in addition to data displays. Because Data display was significantly correlated to the Hooper Visual Organization Test and WAIS-III Picture Completion, these test items may require global processing and visual organization.

Because the test administration was long, in order to facilitate the process for the patients, it may be better to choose representative items to administer. The Hooper Visual Organization Test and WASI-II Matrix Reasoning explained higher percentage in variation of Level 2. Because the cognitive functions these test measure are context related functions, Level 2 items may fit perfectly to administer.

**Limitations and Future Research Suggestions**

Limitations of the study can be identified in terms of the task design, the neuropsychological tests that were utilized to validate the newly developed test, the statistical procedure conducted to validate the test.

This test included task-relevant and task-irrelevant features. The participants were required to understand context by comparing the task relevant features and ignoring task irrelevant features. The number of task irrelevant features presented across the test items may be related to limited working memory capacity (Kosslyn, 1994). The higher number of task
irrelevant features may increase participants’ cognitive load (Kosslyn, 1994; Malamed, 2009). In the future the number of task relevant features can be stabilized across the test items (Kosslyn, 1994; Malamed, 2009). The values of visual variables changed based upon the principle of discriminability and saliency (Hegarty, 2011; Kosslyn, 1994; Munzner, 2015; Ware, 2012). Not all values of all visual variables are differentiated from each other equally accurate (Cleveland & McGill, 1984; Munzner, 2015). For instance, comparing two different values of length can be more accurate than comparing two different values of color saturation (Cleveland & McGill, 1984). Therefore, not all comparisons equally contributed to understanding context. In the future, visual variables may be chosen systematically to examine the contribution of comparisons of visual variables to understanding context. In order to standardize the number of levels of difficulty for each test item, the values of visual variables (e.g., shape, size, length) differentiated at 10 levels regardless of type of visual variables based upon the principle of discriminability. However, as Munzner (2015) indicated, some visual variables (e.g., linewidth) do not vary at 10 noticeable values. Therefore, the visual variables utilized in the test can be standardized in the future studies.

Some of the neuropsychological tests that were utilized to validate the test, may tap into more than one cognitive function. For instance, The WASI-II Block Design has been generally used to measure whether participants understand abstract stimuli (Wechsler, 2011). However, in other studies, it was also measured for local processing (Drake et al., 2010; Drake & Winner, 2011). Therefore, it was not clear which cognitive function was pointed out when incorporated into the statistical analyses. In the future, some other tests can be found that will tap purely into one cognitive domain. Because different sets of neuropsychological test were assigned to the participants, in the multiple regression analyses only the corresponding neuropsychological
tests were included. In the future, taking the results of this study into account, limited neuropsychological tests may be administered. In this study construct validity was attempted to measure through correlations. As Cronbach and Mehl (1955) discussed correlations may not be sufficient to validate a test. In the future, other analyses may be required to crucially examine whether there is one construct. Because short-term carry over effects were anticipated, the subtests were administered in a fixed order (Bell, 2012). However, learning effect may occur in Level 3 Infographics. In the future, the subtests can be presented in randomized order. Although different categories of abstract graphics were classified based upon relationships among the variables, the corresponding cognitive functions underlying each visual display may not be clearly distinguished from each other.

Conclusion

Overall, based upon the given operational definition, the newly developed Infographics test correlated with visual organization and global processing. Unlike WASI-II Matrix Reasoning (visual reasoning), surprisingly, WASI-II Similarities (verbal reasoning) explained higher percentage of variation in all hypotheses. These results may show that there can be another construct related to verbal reasoning. Regardless, participants may use global processing and comparison as processed in the stimulus, although categorize different entities to explain the infographics. Therefore, the test may measure context processing as well as additional cognitive functions.

Although there was only one operational definition of context processing, cognitive functions contributing to context processing may be related to other functions (Franzen et al., 1989). Different methodologies should be taken into account to clarify the operational definition.
Level 1, 2 and 3 items were expected to require different cognitive functions. High percentages of variability in Level 3 was explained by WASI-II Similarities. However, Level 3 was also correlated with the Hooper Visual Organization Test, WASI-II Vocabulary, WAIS-III Picture Completion Test, WASI-II Matrix Reasoning, and WASI-II Vocabulary.

Context can be processed in specific cognitive domains (e.g., working memory) (Cohen & Servan-Schreiber, 1992) or can be generalized from the low-level perceptual processes to higher cognitive domains (Phillips & Silverstein, 2003). In the infographics, color (Munzner, 2015), arrows (Malamed, 2009; Tversky, 2011), and pictograms (Malamed, 2009; Tversky, 2011) can be comprehended within a context. It is not clear if processing context by means of these features may facilitate or may distract functions related to context processing through global processing and comparison. It is still vague whether context processing in comprehension of arrows, and pictograms are related to a specific domain or can be generalized to the other cognitive domains.

The Infographics test was initially intended for patients with schizophrenia. This study aimed only to evaluate context processing on healthy population. Although there was a significant correlation between visual organization and Infographics test, unexpectedly, Similarities accounted for higher percentage of variability in Infographics test items. This unexpected result may enable us to question whether there are other cognitive functions related to context processing, or whether the new test measures other cognitive functions unrelated to context processing. In the future, to examine construct validity, the Infographics and neuropsychological tests should be administered to patients with schizophrenia, and their performance should be compared to an age, education, and ethnicity matched group to comprehend whether these tests measure context processing.
Social Network of Jazz in 1920s New York City

For each of these 24 leading jazz musicians working in New York during the Roaring Twenties, the size of the silhouette depicts the number of recording sessions by that musician during his or her lifetime. The connecting lines show joint recording sessions — a sort of sociogram of Gotham’s jazz scene. (Idea, research, illustration and design by Robert Nippoldt; additional design by Christine Goppel and Tobias Glasmacher; research by the Bavarian Jazz Institute’s Sylke Mehrbold.)

Figure 1. An example of Infographics

Social Network of Jazz in 1920s New York City designed by Robert Nippoldt (additional design by Christine Goppel and Tobias Glasmacher; research by Bavarian Jazz Institute’s Sylke Mehrbold) (Popova, 2014; Silver & Cook, 2014, p.54-55).
What relationship of colors produces thicker lines?

*Figure 2a. An example of Level 1 test items*
How does one of the colors change consistently?

*Figure 2b. An example of Level 1 test items*
Figure 2c. An example of Level 1 test items
What factor predicts the amount of iron on a planet?

Figure 3a. An example of Level 2 test items
What factor increases student enrollment?

Figure 3b. An example of Level 2 test items
Icons retrieved from The Noun Project - www.thenounproject.com
What factors lead to the best luck fishing?

Joe's Pond  |  Jack's Pond  |  Jim's Pond

Sunrise: ☀️  ☀️  ☀️
Sunset: ☀️  ☀️  ☀️  ☀️  ☀️
Noon: ☀️  ☀️  ☀️

Figure 3c: An example of Level 2 test items
Icons retrieved from The Noun Project - www.thenounproject.com
Figure 4a. An example of Level 3 test items
Icons retrieved from The Noun Project - www.thenounproject.com
What factors increase the chance of success?

Figure 4b. An example of Level 3 test items
Icons retrieved from The Noun Project - www.thenounproject.com
Figure 4c. An example of Level 3 test items
Icons retrieved from The Noun Project - www.thenounproject.com
Level 1

Question: What relationship of colors produces thicker lines?

Answer: Dots of the same color produce thicker lines.

Most difficult

Figure 5a. An example of levels of difficulty for Level 1 Infographics.
Level 2

Question: What factors lead to the best luck fishing?

Answer: Fishing in Jim’s pond at sunset

Most difficult

Figure 5b. An example of levels of difficulty for Level 2 Infographics.
Level 3

Question: What factor increases incidence of illness?

Answer: Smoking

Most difficult

Easiest

*Figure 5c.* An example of levels of difficulty for Level 3 Infographics.
Figure 6a. Histogram of Level 1 Item 4 Distribution
Figure 6b. Histogram of Level 1 Item 9 Distribution
Figure 6c. Histogram of Level 1 Item 11 Distribution
Figure 7. Histogram of Distribution of Infographics
Figure 8a. Histogram of Level 1 Infographics Distribution
Figure 8b. Histogram of Level 2 Infographics Distribution
Figure 8c. Histogram of Level 3 Infographics Distribution
Figure 9a. Histogram of Data Display Distribution
Figure 9b. Histogram of Diagram Distribution
Figure 9c. Histogram of Map Distribution
Figure 9d. Histogram of Timeline Distribution
Table 1. *Summary Table of Level of Cognitive Processing and Category of Infographics for Each Item*

<table>
<thead>
<tr>
<th>Category of Infographics</th>
<th>Level of Cognitive Processing</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Level 1</td>
</tr>
<tr>
<td>Data display</td>
<td>1,2,7</td>
</tr>
<tr>
<td>Diagram</td>
<td>3,4,6</td>
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<tr>
<td>Map</td>
<td>5,8,9</td>
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<tr>
<td>Time line</td>
<td>10,11,12</td>
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<td>Test</td>
<td>Cognitive Function</td>
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<td>-----------------------------------------------</td>
<td>--------------------------------------------------------</td>
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<tr>
<td>Trail Making Test- A (TMT A)</td>
<td>Attention</td>
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<tr>
<td>Trail Making Test-B (TMT B)</td>
<td>Task switching</td>
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<td>Navon Global Precedence</td>
<td>Global precedence</td>
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<tr>
<td>Navon Local Processing Task</td>
<td>Local processing</td>
</tr>
<tr>
<td>Hooper Visual Organization Test</td>
<td>Visual perceptual organization</td>
</tr>
<tr>
<td>WASI-II Matrix Reasoning</td>
<td>Visual reasoning, abstract problem solving, spatial ability</td>
</tr>
<tr>
<td>WASI-II Block Design</td>
<td>Local processing, analyzing and synthesizing abstract visual stimuli</td>
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<tr>
<td>WASI-II Similarities</td>
<td>Verbal reasoning, categorization</td>
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<tr>
<td>WASI-II Vocabulary</td>
<td>Word knowledge</td>
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<td>WAIS-III Picture Completion Test</td>
<td>Global processing by paying attention on details</td>
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<td>Graphical Literacy Scale Total</td>
<td>Graphical skills that will contain quantitative information</td>
</tr>
<tr>
<td>Graphical Literacy Scale A</td>
<td>Reading data</td>
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<tr>
<td>Graphical Literacy Scale B</td>
<td>Finding associations between two data points</td>
</tr>
<tr>
<td>Graphical Literacy Scale C</td>
<td>Interpreting the results beyond the given data</td>
</tr>
<tr>
<td>Judgment of Line Orientation Test (JLO)</td>
<td>Spatial perception and spatial orientation</td>
</tr>
<tr>
<td>WMS-III Spatial Span</td>
<td>Spatial working memory test</td>
</tr>
<tr>
<td>Number of Participants</td>
<td>Reason for the exclusion - provide the reasons</td>
</tr>
<tr>
<td>------------------------</td>
<td>----------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>8 (full)</td>
<td>Confusion with the folders</td>
</tr>
<tr>
<td>5 (full)</td>
<td>Neuropsychological tests were not administered and demographics were not clear-</td>
</tr>
<tr>
<td>1 (full)</td>
<td>Different order from the rest</td>
</tr>
<tr>
<td>21 (partial)</td>
<td>Spatial span test was not administered based on the instructions</td>
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<tr>
<td>11 (partial)</td>
<td>Similarities, vocabulary and picture completion test were administered without providing the queries</td>
</tr>
<tr>
<td>4 (partial)</td>
<td>H1-navon technical problems</td>
</tr>
<tr>
<td>31 (partial)</td>
<td>Infographics test items</td>
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<tr>
<td>Type of skewed data</td>
<td>Formulae</td>
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<td>------------------------------------</td>
<td>-----------------------------------------------</td>
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<tr>
<td>Moderately positively skewed data</td>
<td>SQRT (test score)</td>
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<tr>
<td>Moderately negatively skewed data</td>
<td>SQRT (1+max-test score)</td>
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<td>LG10 (test score)</td>
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<td>Strongly negatively skewed data</td>
<td>LG10(1+max-test score)</td>
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<tr>
<td>Extremely positively skewed data</td>
<td>1/test score</td>
</tr>
<tr>
<td>Extremely negatively skewed data</td>
<td>1/(1+max-test score)</td>
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<table>
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<tr>
<th>Test Item</th>
<th>N</th>
<th>M</th>
<th>SD</th>
<th>Range (Level of Difficulty)</th>
<th>Skewness</th>
<th>SEskewness</th>
<th>Zskewness</th>
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<td>1.68</td>
</tr>
<tr>
<td>L3 I8</td>
<td>113</td>
<td>3.1504</td>
<td>2.19261</td>
<td>1-11</td>
<td>2.107</td>
<td>0.227</td>
<td>9.28</td>
<td>1.79</td>
</tr>
<tr>
<td>L3 I9</td>
<td>84</td>
<td>6.9643</td>
<td>2.67269</td>
<td>1-11</td>
<td>-0.004</td>
<td>0.263</td>
<td>-0.02</td>
<td>-0.02</td>
</tr>
<tr>
<td>L3 I10</td>
<td>100</td>
<td>4.0800</td>
<td>2.29043</td>
<td>1-11</td>
<td>1.161</td>
<td>0.241</td>
<td>4.82</td>
<td>-1.16</td>
</tr>
<tr>
<td>L3 I11</td>
<td>99</td>
<td>3.2121</td>
<td>1.88047</td>
<td>1-11</td>
<td>1.923</td>
<td>0.243</td>
<td>7.91</td>
<td>0.70</td>
</tr>
<tr>
<td>L3 I12</td>
<td>100</td>
<td>4.2800</td>
<td>2.13712</td>
<td>1-11</td>
<td>1.083</td>
<td>0.241</td>
<td>4.49</td>
<td>0.26</td>
</tr>
</tbody>
</table>

*Note:* ±1.96 was accepted as a z critical value (Pett, 2015). Items that are red highlighted in the Z skewness column were accepted as non-normal distributed (beyond ±1.96).
<table>
<thead>
<tr>
<th>Item Name</th>
<th>N</th>
<th>M</th>
<th>SD</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Skewness</th>
<th>SE skewness</th>
<th>Z skewness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Navon reaction time Global</td>
<td>26</td>
<td>1004.73</td>
<td>243.97</td>
<td>563.00</td>
<td>1525.00</td>
<td>.404</td>
<td>.456</td>
<td>0.89</td>
</tr>
<tr>
<td>Navon reaction time Local</td>
<td>26</td>
<td>958.88</td>
<td>232.61</td>
<td>592.00</td>
<td>1569.00</td>
<td>.886</td>
<td>.456</td>
<td>1.94</td>
</tr>
<tr>
<td>Block Design</td>
<td>29</td>
<td>42.44</td>
<td>10.41</td>
<td>25.00</td>
<td>59.00</td>
<td>-.020</td>
<td>.434</td>
<td>-.05</td>
</tr>
<tr>
<td>Hooper Visual Organization Test</td>
<td>28</td>
<td>23.96</td>
<td>3.91</td>
<td>15.00</td>
<td>30.00</td>
<td>-.830</td>
<td>.441</td>
<td>-1.88</td>
</tr>
<tr>
<td>TMTA</td>
<td>27</td>
<td>25906.11</td>
<td>6508.45</td>
<td>12006.00</td>
<td>38000.00</td>
<td>-.041</td>
<td>.448</td>
<td>-0.09</td>
</tr>
<tr>
<td>TMTB</td>
<td>25</td>
<td>46407.84</td>
<td>13634.65</td>
<td>23070.00</td>
<td>80030.00</td>
<td>1.148</td>
<td>.464</td>
<td>2.47</td>
</tr>
<tr>
<td>Similarities</td>
<td>26</td>
<td>32.96</td>
<td>3.48</td>
<td>25.00</td>
<td>39.00</td>
<td>-.514</td>
<td>.456</td>
<td>-1.13</td>
</tr>
<tr>
<td>Vocabulary</td>
<td>26</td>
<td>39.42</td>
<td>3.57</td>
<td>31.00</td>
<td>48.00</td>
<td>.106</td>
<td>.456</td>
<td>0.23</td>
</tr>
<tr>
<td>Picture Completion Test</td>
<td>26</td>
<td>20.769</td>
<td>2.65</td>
<td>13.00</td>
<td>25.00</td>
<td>-1.019</td>
<td>.456</td>
<td>-2.23</td>
</tr>
<tr>
<td>Spatial Span Test</td>
<td>27</td>
<td>15.25</td>
<td>2.17</td>
<td>11.00</td>
<td>20.00</td>
<td>.172</td>
<td>.448</td>
<td>0.38</td>
</tr>
<tr>
<td>Graphical Literacy A</td>
<td>48</td>
<td>3.77</td>
<td>.47</td>
<td>2.00</td>
<td>4.00</td>
<td>-1.944</td>
<td>.343</td>
<td>-5.67</td>
</tr>
<tr>
<td>Graphical Literacy B</td>
<td>48</td>
<td>3.39</td>
<td>.76</td>
<td>2.00</td>
<td>4.00</td>
<td>-.825</td>
<td>.343</td>
<td>-2.41</td>
</tr>
<tr>
<td>Graphical Literacy C</td>
<td>48</td>
<td>2.56</td>
<td>1.16</td>
<td>.00</td>
<td>5.00</td>
<td>-.242</td>
<td>.343</td>
<td>-0.71</td>
</tr>
<tr>
<td>Graphical Literacy Total</td>
<td>48</td>
<td>9.72</td>
<td>1.77</td>
<td>6.00</td>
<td>13.00</td>
<td>-.360</td>
<td>.343</td>
<td>-1.05</td>
</tr>
<tr>
<td>Benton Judgment Line Orientation Test</td>
<td>48</td>
<td>24.64</td>
<td>3.37</td>
<td>16.00</td>
<td>30.00</td>
<td>-.363</td>
<td>.343</td>
<td>-1.06</td>
</tr>
<tr>
<td>Matrix Reasoning</td>
<td>113</td>
<td>19.7434</td>
<td>3.16730</td>
<td>11.00</td>
<td>26.00</td>
<td>-.543</td>
<td>.227</td>
<td>-2.39</td>
</tr>
</tbody>
</table>
Table 7. *Descriptive Statistics for Average Scores (Z Scores of Transformed Average Scores)*

<table>
<thead>
<tr>
<th>Test Item</th>
<th>N</th>
<th>Minimum</th>
<th>Maximum</th>
<th>M</th>
<th>SD</th>
<th>Skewness</th>
<th>SE_{skewness}</th>
<th>Z_{skewness}</th>
</tr>
</thead>
<tbody>
<tr>
<td>Infographics</td>
<td>114</td>
<td>-.93</td>
<td>.92</td>
<td>.0027</td>
<td>.36470</td>
<td>-.083</td>
<td>.226</td>
<td>-.3672566</td>
</tr>
<tr>
<td>Level 1</td>
<td>114</td>
<td>-1.05</td>
<td>.91</td>
<td>.0003</td>
<td>.40746</td>
<td>.077</td>
<td>-.456</td>
<td>-0.1688596</td>
</tr>
<tr>
<td>Level 2</td>
<td>114</td>
<td>-1.11</td>
<td>1.17</td>
<td>-.0016</td>
<td>.46087</td>
<td>.247</td>
<td>.226</td>
<td>1.09292035</td>
</tr>
<tr>
<td>Level 3</td>
<td>113</td>
<td>-1.10</td>
<td>1.14</td>
<td>.0018</td>
<td>.47430</td>
<td>.144</td>
<td>.227</td>
<td>.63436123</td>
</tr>
<tr>
<td>Data Display</td>
<td>114</td>
<td>-1.36</td>
<td>1.42</td>
<td>.0153</td>
<td>.54240</td>
<td>.011</td>
<td>.226</td>
<td>0.04867257</td>
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<tr>
<td>Diagram</td>
<td>114</td>
<td>-.94</td>
<td>1.12</td>
<td>-.0011</td>
<td>.43384</td>
<td>.310</td>
<td>.226</td>
<td>1.37168142</td>
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<td>Map</td>
<td>114</td>
<td>-.93</td>
<td>1.65</td>
<td>.0134</td>
<td>.45450</td>
<td>.424</td>
<td>.226</td>
<td>1.87610619</td>
</tr>
<tr>
<td>Timeline</td>
<td>114</td>
<td>-1.01</td>
<td>1.25</td>
<td>.0024</td>
<td>.46983</td>
<td>-.031</td>
<td>.226</td>
<td>-0.1371681</td>
</tr>
</tbody>
</table>
Table 8a. **Pearson Correlation Coefficient between Z Scores of Neuropsychological Test Scores and Z Scores of Transformed Average Scores**

<table>
<thead>
<tr>
<th>Test</th>
<th>Average Infographics Scores</th>
</tr>
</thead>
<tbody>
<tr>
<td>Navon Global (n=25)</td>
<td>.088 (.675)</td>
</tr>
<tr>
<td>Navon Local (n=25)</td>
<td>-.133 (.526)</td>
</tr>
<tr>
<td>Block Design (n=28)</td>
<td>-.156 (.428)</td>
</tr>
<tr>
<td>Hooper Visual Organization Test (n=27)</td>
<td>-.482 (.011)*</td>
</tr>
<tr>
<td>TMTA (n=26)</td>
<td>.276 (.173)</td>
</tr>
<tr>
<td>TMTB (n=23)</td>
<td>.297 (.169)</td>
</tr>
<tr>
<td>Similarities (n=26)</td>
<td>-.637 (.000)**</td>
</tr>
<tr>
<td>Vocabulary (n=24)</td>
<td>-.492 (.015)*</td>
</tr>
<tr>
<td>Picture Completion (n=25)</td>
<td>-.428 (.033)*</td>
</tr>
<tr>
<td>Spatial Span Test</td>
<td>-.085 (.672)</td>
</tr>
<tr>
<td>Graphical Literacy Scale (n=47)</td>
<td>-.449 (.002)**</td>
</tr>
<tr>
<td>Benton Judgment of Line of Orientation (n=46)</td>
<td>-.284 (.056)</td>
</tr>
<tr>
<td>Matrix Reasoning (n=112)</td>
<td>-.373 (.000)**</td>
</tr>
</tbody>
</table>

*p<.05 **p<.01

Table 8b. **Spearman Correlation between Z Scores of Graphical B and Graphical C tests and Z Scores of Transformed Average Scores**

<table>
<thead>
<tr>
<th>Test</th>
<th>Average Infographics Scores</th>
</tr>
</thead>
<tbody>
<tr>
<td>Graphical A</td>
<td>-.136 (.364)</td>
</tr>
<tr>
<td>Graphical B</td>
<td>-.361 (.013)*</td>
</tr>
<tr>
<td>Graphical C</td>
<td>-.354 (.015)*</td>
</tr>
</tbody>
</table>

*p<.05 **p<.01
Table 9a. Pearson Correlation Coefficient between Z Scores of Neuropsychological Test Scores and Z Scores of Transformed Average Scores for Each Level of Cognitive Processing

<table>
<thead>
<tr>
<th>Test Items</th>
<th>Average Level 1 Test Items</th>
<th>Average Level 2 Test Items</th>
<th>Average Level 3 Test Items</th>
</tr>
</thead>
<tbody>
<tr>
<td>Navon Global</td>
<td>.120 (.568)</td>
<td>.021 (.919)</td>
<td>.099 (.637)</td>
</tr>
<tr>
<td>Navon Local</td>
<td>-.038 (.856)</td>
<td>-.197 (.346)</td>
<td>-.083 (.692)</td>
</tr>
<tr>
<td>Block Design</td>
<td>-.067 (.734)</td>
<td>-.213 (.277)</td>
<td>-.089 (.654)</td>
</tr>
<tr>
<td>Hooper Visual Organization Test</td>
<td>-.176 (.379)</td>
<td>-.542 (.003)**</td>
<td>-.414 (.032)*</td>
</tr>
<tr>
<td>TMTA</td>
<td>-.107 (.603)</td>
<td>.396 (.045)*</td>
<td>.300 (.137)</td>
</tr>
<tr>
<td>TMTB</td>
<td>.238 (.274)</td>
<td>.231 (.289)</td>
<td>.298 (.168)</td>
</tr>
<tr>
<td>Similarities</td>
<td>-.403 (.041)*</td>
<td>-.599 (.001)**</td>
<td>-.601 (.001)**</td>
</tr>
<tr>
<td>Vocabulary</td>
<td>-.345 (.098)</td>
<td>-.398 (.054)</td>
<td>-.515 (.010)*</td>
</tr>
<tr>
<td>Picture Completion</td>
<td>-.441 (.027)*</td>
<td>-.263 (.204)</td>
<td>-.440 (.028)*</td>
</tr>
<tr>
<td>Spatial Span Test</td>
<td>-.159 (.427)</td>
<td>-.113 (.575)</td>
<td>-.291 (.149)</td>
</tr>
<tr>
<td>Graphical Total</td>
<td>-.183 (.219)</td>
<td>-.492 (.000)**</td>
<td>-.321 (.028)*</td>
</tr>
<tr>
<td>Benton Judgment Line of Orientation</td>
<td>-.328 (.026)*</td>
<td>-.201 (.181)</td>
<td>-.052 (.733)</td>
</tr>
<tr>
<td>Matrix Reasoning</td>
<td>-.223 (.018)*</td>
<td>-.361 (.000)**</td>
<td>-.312 (.001)**</td>
</tr>
</tbody>
</table>

*p<.05 **p<.01

Table 9b. Spearman Correlation between Z Scores of Graphical B and Graphical C tests and Z Scores of Transformed Average Scores for Each Level of Cognitive Processing

<table>
<thead>
<tr>
<th>Test Items</th>
<th>Average Level 1 Test Items</th>
<th>Average Level 2 Test Items</th>
<th>Average Level 3 Test Items</th>
</tr>
</thead>
<tbody>
<tr>
<td>Graphical A</td>
<td>-.056 (.709)</td>
<td>.008 (.958)</td>
<td>-.147 (.322)</td>
</tr>
<tr>
<td>Graphical B</td>
<td>-.140 (.347)</td>
<td>-.350 (.016)*</td>
<td>-.280 (.057)</td>
</tr>
<tr>
<td>Graphical C</td>
<td>-.150 (.315)</td>
<td>-.409 (.004)**</td>
<td>-.191 (.198)</td>
</tr>
</tbody>
</table>

*p<.05 **p<.01
### Table 10a. Pearson Correlation Coefficient between Z Scores of Neuropsychological Test Scores and Z Scores of Transformed Average Scores for Each Category of Infographics

<table>
<thead>
<tr>
<th></th>
<th>Data Display</th>
<th>Diagram</th>
<th>Maps</th>
<th>Timeline</th>
</tr>
</thead>
<tbody>
<tr>
<td>Navon Global</td>
<td>.125 (.552)</td>
<td>-.018 (.931)</td>
<td>.097 (.646)</td>
<td>.044 (.835)</td>
</tr>
<tr>
<td>Navon Local</td>
<td>-.056 (.790)</td>
<td>-.123 (.557)</td>
<td>-.055 (.795)</td>
<td>-.202 (.333)</td>
</tr>
<tr>
<td>Block Design</td>
<td>-.117 (.555)</td>
<td>-.085 (.669)</td>
<td>-.161 (.412)</td>
<td>-.101 (.609)</td>
</tr>
<tr>
<td>Hooper Visual Organization Test</td>
<td>-.428 (.026)*</td>
<td>-.276 (.164)</td>
<td>-.354 (.070)</td>
<td>-.361 (.064)</td>
</tr>
<tr>
<td>TMTA</td>
<td>.220 (.281)</td>
<td>.243 (.231)</td>
<td>.017 (.936)</td>
<td>.383 (.054)</td>
</tr>
<tr>
<td>TMTB</td>
<td>.335 (.118)</td>
<td>.044 (.843)</td>
<td>.192 (.380)</td>
<td>.313 (.145)</td>
</tr>
<tr>
<td>Similarities</td>
<td>-.643 (.000)**</td>
<td>-.494 (.010)*</td>
<td>-.593 (.001)**</td>
<td>-.426 (.030)*</td>
</tr>
<tr>
<td>Vocabulary</td>
<td>-.444 (.030)*</td>
<td>-.369 (.076)</td>
<td>-.439 (.032)**</td>
<td>-.424 (.039)*</td>
</tr>
<tr>
<td>Picture Completion</td>
<td>-.520 (.007)*</td>
<td>-.520 (.008)*</td>
<td>-.370 (.135)</td>
<td>-.103 (.625)</td>
</tr>
<tr>
<td>Spatial Span Test</td>
<td>-.130 (.518)</td>
<td>.065 (.747)</td>
<td>.250 (.209)</td>
<td>.083 (.685)</td>
</tr>
<tr>
<td>Graphical Literacy Total Score</td>
<td>-.387 (.007)**</td>
<td>-.314 (.032)*</td>
<td>-.424 (.003)**</td>
<td>-.244 (.099)</td>
</tr>
<tr>
<td>Benton Judgment Line of Orientation</td>
<td>-.252 (.091)</td>
<td>-.273 (.066)</td>
<td>-.146 (.333)</td>
<td>-.093 (.540)</td>
</tr>
<tr>
<td>Matrix Reasoning</td>
<td>-.316 (.001)**</td>
<td>-.333 (.000)**</td>
<td>-.255 (.007)**</td>
<td>-.230 (.015)*</td>
</tr>
</tbody>
</table>

*p<.05 **p<.01

### Table 10b. Spearman Correlation between Z Scores of Graphical B and Graphical C tests and Z Scores of Transformed Average Scores for Each Category of Infographics

<table>
<thead>
<tr>
<th></th>
<th>Data Display</th>
<th>Diagram</th>
<th>Maps</th>
<th>Timeline</th>
</tr>
</thead>
<tbody>
<tr>
<td>Graphical A</td>
<td>-.140 (.350)</td>
<td>-.048 (.749)</td>
<td>-.231 (.118)</td>
<td>-.008 (.958)</td>
</tr>
<tr>
<td>Graphical B</td>
<td>-.394 (.006)*</td>
<td>-.163 (.273)</td>
<td>-.340 (.019)*</td>
<td>-.142 (.340)</td>
</tr>
<tr>
<td>Graphical C</td>
<td>-.309 (.034)*</td>
<td>-.266 (.071)</td>
<td>-.306 (.037)*</td>
<td>-.201 (.175)</td>
</tr>
</tbody>
</table>

*p<.05 **p<.01
### Appendix A

The Levels of Cognitive Processing, Category of Infographics, Questions, Answers

<table>
<thead>
<tr>
<th>Level of Cognitive Processing</th>
<th>The number and the name of the test item</th>
<th>The Category of Infographics</th>
<th>Question</th>
<th>Answer</th>
<th>Image</th>
</tr>
</thead>
<tbody>
<tr>
<td>Practice Question (general)</td>
<td>Media</td>
<td>Data Display (P)</td>
<td>Which Media lasted longest?</td>
<td>CD</td>
<td><img src="image1.png" alt="Image" /></td>
</tr>
<tr>
<td>Practice Question (Level 1)</td>
<td>The squares</td>
<td>Data display (P)</td>
<td>What is consistent across the squares?</td>
<td>There are the same number of squares in the left and the right side of the page</td>
<td><img src="image2.png" alt="Image" /></td>
</tr>
<tr>
<td>1</td>
<td>1-red-circle</td>
<td>Data display</td>
<td>How does one of these shapes cause the circle to get darker?</td>
<td>The size of the triangle/ the bigger triangle the darker the circle</td>
<td><img src="image3.png" alt="Image" /></td>
</tr>
<tr>
<td>1</td>
<td>2-barchart consistency</td>
<td>Data display</td>
<td>How does one of the colors change consistently?</td>
<td>Orange bars consistently increase.</td>
<td><img src="image4.png" alt="Image" /></td>
</tr>
<tr>
<td>1</td>
<td>3-node-link size shape</td>
<td>Diagram</td>
<td>What relationship of colors produces thicker lines?</td>
<td>Connecting same dots/same color dots Blue/blue green/green orange/orange</td>
<td><img src="image5.png" alt="Image" /></td>
</tr>
<tr>
<td>1</td>
<td>4-process-circle arrow</td>
<td>Diagram</td>
<td>What is the relationship between the arrows and the numbers</td>
<td>The arrows become larger when the difference between the numbers are greater</td>
<td><img src="image6.png" alt="Image" /></td>
</tr>
<tr>
<td>1</td>
<td>5- above- below processes</td>
<td>Map</td>
<td>What is the spatial relationship between pentagons and circles?</td>
<td>The circles are above and the pentagons are below</td>
<td><img src="image7.png" alt="Image" /></td>
</tr>
<tr>
<td>1</td>
<td>6-Node-link hierarchy</td>
<td>Diagram</td>
<td>How do colors under red differ from colors under the blue, orange, and green?</td>
<td>Red box will lead to two boxes in the same/identical colors</td>
<td></td>
</tr>
<tr>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>7-Doughnut Chart</td>
<td>Data display</td>
<td>What causes the circle to get darker?</td>
<td>The more/bigger/larger/larger yellow the darker the circle</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>8-Bubble regions</td>
<td>Map</td>
<td>What is consistent in one of the rows?</td>
<td>One row has the same number of dots</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>9-Color regions</td>
<td>Map</td>
<td>What factor reduces the size of the circle?</td>
<td>The shape become longer As the shapes become rectangle the circles become smaller</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>10-Timeline (1)</td>
<td>Timeline</td>
<td>What consistency exists along the arrow?</td>
<td>The numbers of dots increase as they are progressing along the arrow or vice versa</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>11-Timeline(2)</td>
<td>Timeline</td>
<td>What consistency exists in this pattern?</td>
<td>The Ls become smaller as they go from left to right.(from larger to smaller)- or vice versa</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>12-Timeline (3)</td>
<td>Timeline</td>
<td>What color decreases consistently</td>
<td>Purple/Blue</td>
<td></td>
</tr>
<tr>
<td>Practice Question Level 2</td>
<td>Games</td>
<td>Not specified (P)</td>
<td>What factor increases the number of games?</td>
<td>At the beginning of the week there are more basketball games, at the end of the week there are more soccer games.</td>
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<tr>
<td>2</td>
<td>1-Barchart consistency-sales cell phone</td>
<td>Data display</td>
<td>How does one of the item sales consistently change?</td>
<td>Macbook sales increase across years</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>2-Maps</td>
<td>Map</td>
<td>What factor predicts increased tea drinkers?</td>
<td>There are more tea drinkers in the southern hemisphere/be low the equator</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>3-Baking muffins effort</td>
<td>Timeline</td>
<td>What factors in baking causes the greatest amount of fatigue?</td>
<td>The more time spent using hands the more fatigue.</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>4-Baking sugar oven heat</td>
<td>Data display</td>
<td>What factor is related to higher oven temperature?</td>
<td>The greater amount of sugar, the higher the temperature.</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>5-Planets iron</td>
<td>Data display</td>
<td>What factor predicts the amount of iron in a planet?</td>
<td>The closer to the sun and the more iron (the darkest the red)</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>6. Fisherman</td>
<td>Timeline</td>
<td>What factor leads to the best luck fishing?</td>
<td>When the fisherman in the big lake catches the most fish at sunset/ Jim’s pond and sunset</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>7- Diagonal Circle Center Focus</td>
<td>Diagram</td>
<td>What factor is related to the greatest success of an activity?</td>
<td>The more people contribute to the project the more success they will have.</td>
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<tr>
<td>2</td>
<td>8-Coffee-world map with lines</td>
<td>Map</td>
<td>What factor predicts amount of coffee exported from Colombia?</td>
<td>There are more coffee beans exports close to the north pole</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>9- Dog Silhouette</td>
<td>Timeline</td>
<td>What factor most affects the dog’s growth?</td>
<td>The breed of dog. All dogs grow bigger as the times progress. The dogs grow bigger in relation to the original size. Small dogs grow smaller, big dogs grow exponentially with age.</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>10-Subway Stations</td>
<td>Map</td>
<td>What factor reduces travel time?</td>
<td>The fewer/less stops</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>11- Lecturer Lab hierarchy</td>
<td>Diagram</td>
<td>What factor increases student enrollment?</td>
<td>When there is a morning lecturer and an evening lab instructor</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>12- Sharing the soccer balls</td>
<td>Diagram</td>
<td>How can teams reduce expenses?</td>
<td>Being able to share the balls/using the same balls</td>
<td></td>
</tr>
<tr>
<td>Practice Question Level 3</td>
<td>Plant productivity</td>
<td>Data display (P)</td>
<td>What factor reduces the productivity?</td>
<td>As the amount of rainfall increase the number of trees increase and the</td>
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<td>3</td>
<td>1. production corn</td>
<td>Diagram</td>
<td>What factor increases farm production?</td>
<td>Environmenta l (natural) factors will contribute more to the production in farm.</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>2- Timeline</td>
<td>Timeline</td>
<td>What activity throughout a lifetime involves highest interactions with people?</td>
<td>Education/ To be involved in education/ Going to school</td>
<td></td>
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<tr>
<td>3</td>
<td>3- Overweight-normal weight</td>
<td>Timeline</td>
<td>What factor helps control weight?</td>
<td>Eating healthy food preceding midnight/ before going to bed or avoiding eating junk food</td>
<td></td>
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<tr>
<td>3</td>
<td>4- Health Factories</td>
<td>Map</td>
<td>What factor increases incidence of illness?</td>
<td>Smoking/ Using tobacco</td>
<td></td>
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<tr>
<td>3</td>
<td>5-Uber pool</td>
<td>Map</td>
<td>What type of transportation is good for short trips but bad for long trips?</td>
<td>Without transportation/ without vehicles/ physical activity</td>
<td></td>
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<tr>
<td>3</td>
<td>6-Central park</td>
<td>Map</td>
<td>What are the best places to sell ice cream?</td>
<td>Next to the children’s parks/kids/ kids related places/playgrounds</td>
<td></td>
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<tr>
<td>3</td>
<td>7-Monthly bill</td>
<td>Data display</td>
<td>What factors increase the monthly bill?</td>
<td>The more kitchen gadgets with electricity is used the higher the electric bill will be.</td>
<td></td>
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<tr>
<td>3</td>
<td>8-Horizontal bar graph</td>
<td>Data display</td>
<td>What factor increases the</td>
<td>Art related departments</td>
<td></td>
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<td>3</td>
<td>9-Success</td>
<td>Timeline</td>
<td>What factor increase the chance of success?</td>
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<td></td>
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<td></td>
<td>As the semester progresses or at the end of the semester the students will take more courses related to science field.</td>
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<tr>
<td>3</td>
<td>10-Building a house</td>
<td>Diagram</td>
<td>What type of building material is needed more for residential homes, but less for factories?</td>
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<td></td>
<td></td>
<td></td>
<td>Wood/Trees</td>
<td></td>
<td></td>
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<tr>
<td>3</td>
<td>11-Hobbies</td>
<td>Diagram</td>
<td>What type of hobby is more interesting for Californians, but less interesting for New Yorkers?</td>
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<td></td>
<td></td>
<td></td>
<td>Sports Games</td>
<td></td>
<td></td>
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<tr>
<td>3</td>
<td>12-Homeless Shelters</td>
<td>Data display</td>
<td>What type of donation items are good for a men’s shelter, but bad for a women’s shelter?</td>
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<td></td>
<td></td>
<td></td>
<td>Clothing</td>
<td></td>
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Appendix B

Instructions
Infographics Tests:

**General Instructions:** “You will be shown graphical items along with the questions and figure legends. You will be allowed to read the question and the figure legend before each level of item will be shown. The question and the figure legend will also be presented with items. Each item will have 10 levels of difficulty and begin to be shown from the most difficult level. Each level will appear for 5 seconds, followed by a 5-second blank screen. The next level of the test item will then appear, followed by another 5-second blank screen. The difficulty level at which you first provide an acceptable answer will serve as the correct answer. When you have an answer please provide it verbally to the experimenter. If you cannot find the right answer, the procedure will continue until all 10 levels of difficulty are displayed.”

The paragraph above is written at the beginning of the slides. The experimenter will read the paragraph out-loud to the participant and make sure that each sentence is comprehended clearly.

Because each question contains various types of task relevant features depending on the question, the prompts can vary from question to question. However, these are the general rules that can be followed throughout the test administration.

**Specific Instructions:** Subtest 1: “In the first level, you will see abstract images such as color, shape, size etc. You will answer the questions based on the image.”

Subtest 2: ”In the second level, you will see abstract images or icons that will represent the real-world images along with the legends. You’ll answer the questions based on the images.”

Subtest 3: “In the second level, you will see abstract images or icons that will represent the real-world images along with the legends. You’ll answer the questions based on the images by categorizing the images.”
After the sentences above are read out loud by the experimenter to ensure that the participant will follow the same script on the slides and comprehend each sentence, the following sentences will be explained to the participant verbally (they are not written on the slides).

As seen above, the brief definition and instructions of each subtest are given on the slides and verbally explained by the examiner. As seen below, the detailed instructions for each subtest are only explained verbally to the participant before and after each corresponding practice phase was provided.

“We will provide 4 practice questions in total. Before we start with each subtest we will provide a separate practice phase. We will make sure that you understand the subtests and then we will start with the actual test.” (Throughout the practice phase prompts are provided to make the participant familiar with the prompts.)

**Practice Phase (General):** “The first practice question will show how the levels of difficulty are changed across the levels. If you are ready we can start with the practice phase for the general test.”

After the administration of the first practice question, the experimenter will ensure that the participant understands how the levels of difficulty will be changed (you can ask if that’s clear!)

**Practice Phase (Subtest 1):** Right after the general practice phase, the practice phase for subtest 1 will be presented.

“If you are ready we can start with the practice phase for subtest 1.”

After the administration of the practice phase, regardless of the participant’s answer (whether it is correct or not), the specific explanation for this subtest will be given to show the details on this item:

“If you only focus on the local regions [one of the local regions will be pointed out], you cannot find the correct answer- you need to look around to answer the questions correctly.”
“There will be distractors [the distractors will be pointed out on the image] in the test items. You need to avoid them to answer the questions correctly.”

“We will give you as much time as you want for the question at the beginning of each test item (at least 5 seconds). If you need more time, let us know. After we start administering the test items we will not give extra time for each level.”

After the experimenter ensures that all the instructions are clear for subtest 1, the experimenter will start with the first item of subtest 1.

**Practice Phase (Subtest 2):** After subtest 1 is complete, the experimenter will provide the practice phase for subtest 2.

Before the experimenter will start the administration of the practice phase for subtest 2, he/she will tell the participant that in the second subtest he/she will view again the abstract size, shape, color and icons that will represent the real-world images. He/she needs to apply their answers to real-world applications.

After the administration of the practice phase, regardless of the participant’s answer (whether it is correct or not), the experimenter will provide the explanation for the corresponding subtest to show the details on this item:

“If your answer only includes the features such as colors (e.g. green, blue), we will not accept. You need to provide the exact real-world application (e.g. basketball, soccer).”

“If you only tell the day of the week, we will not accept. You need to be more specific (Monday, Friday, towards the end of the week).”

“You need to combine these two features and tell us the answer.”

After the experimenter ensures that all the instructions are clear for the subtest 2, he/she will start with the first item of subtest 2.

**Practice Phase (Subtest 3):** After the administration of the subtest 2, the experimenter will start with the practice phase for subtest 3.

Before the experimenter will start administering the practice phase for subtest 3, he/she will tell the participant that he/she will view again the abstract size, shape, color and icons that will
represent the real-world images. He/she needs to apply their answers to the real-world applications and he/she needs to categorize the images.

After the administration of the practice phase, regardless of the participant’s answer (whether it is correct or not), the experimenter will explain the item in detail and provide the specific explanation for this item.

“If your answer only includes the features such as colors (e.g. black or white) or icons (tree), we will not accept. If your answer only includes only real-world application (e.g. apple trees, banana trees) we will not accept. You need to categorize apples and bananas and say fruit trees.”

“You need to combine these two features and tell us the answer.”

**Prompts/ Guidance throughout the administration**

Questions:

- If the participant does not understand the question, the experimenter will ask the question in a different way by using the same words (the experimenter will not change anything from the actual question).

- If the experimenter is not sure about the participant’s answer, he/she will ask “What is your answer?”

- If the participant’s answer is correct. The experimenter will say “That’s right”.

- The experimenter does not repeat the question during the administration of a specific item, he/she will provide at least 5 seconds to the participant before he/she presents each item.

- If the participant refers to a part of the question that is not directly relevant, the experimenter will point out the relevant part of the question.

Ex: Question: What factor reduces travel time?

Participant’s answer: More subway stations.

Prompt: We ask for “Reducing travel time” or “Reducing travel time” is asked (the prompt can be either in passive or active voice).

Participant’s answer: Fewer subway stations.
Ex: Question: What type of hobby is more interesting for Californians, but less interesting for New Yorkers?
Participant’s answer: Board games are more interesting for New Yorkers
Prompt: We ask for “hobbies for Californians” or “hobbies for Californians” are asked (the prompt can be either in passive or active voice).
Participant’s answer: Sports are interesting for Californians

After each task, if the participant does not answer the question correctly, the experimenter will provide corrective feedback and explain the answer to the participant and ensure that the answer is comprehended.

Task relevant:
• If the participant has not responded in the first level, the experimenter will prompt him/her by asking “Do you have an answer?” =”Do you have any guess”?
  • If the participant’s answer contains a task relevant feature, but does not contain correct answers (partially correct), the experimenter will prompt him/her by asking What do you mean by “repeat the word the participant tell you”?
Ex: Participant’s answer: Yellow
Prompt: What do you mean by “yellow”-
Participant’s answer: Yellow part is getting larger
  • If the participant’s answer contains a general idea of task relevant features, but does not contain correct answers, the experimenter will prompt him/her by asking What do you mean by “repeat the word the participant tells you”? Be more specific/
Ex: Participant’s answer: The shapes are changing by their size-
Prompt: What do you mean by “shape” and what do you mean by “size”! Be more specific!
Participant’s answer: Yellow part is getting larger
  • If the correct answer contains two relevant features and the participant’s answer contains only one of the task relevant features but not the other one, the experimenter will prompt
him/her by repeating the word the participant tells the experimenter (a task relevant feature) and what else do you see?

Ex: If the answer contains both “Jim’s pond (task relevant) and sunset (task relevant)”

Participant’s answer: “Jim’s pond”

Prompt: “Jim’s pond and what else do you see?”

Participant’s answer: Jim’s pond at sunset

- For level 3, if the participant only tells two visible features, but not the category that these features belong to, the experimenter will prompt him/her by asking “How can you categorize them together”?

Ex: Participant’s answer: Sun and water

Prompt: How can you categorize them together?

Participant’s answer: Natural sources

- For level 3, for the time involved questions, if the participant’s answer contains only one answer, the experimenter will prompt him/her by asking what do you mean?-How does it change?

Ex: Participant’s answer: Healthy food.

Prompt: What do you mean by “healthy food”? How does it change?

Participant’s answer: Before going to bed, eating healthy food.

Task irrelevant:

- If the participant’s answer contains one or more than one task irrelevant features, prompt him/her by asking “Look at the picture again- what else do you see”?

Ex: Participant’s answer: Blue

Prompt: Look at the picture again- what else do you see?

Participant’s answer: Orange

- If the participant’s answer contains one task-relevant and one task-irrelevant feature, and the question does not contain the following words “factor/factors/one of the shapes” prompt him/her by saying “be more specific!”.

Ex: Participant’s answer: yellow (task relevant) and orange (task irrelevant)

Prompt: Be more specific

Participant’s answer: Yellow
• If the participant’s answer contains one task-relevant and one task-irrelevant feature, and the question contains one of the following words “factor/factors/one of the shapes”?, prompt him/her by saying “one factor is asked” or “one of the shapes is asked”.

Ex: Participant’s answer: Orange and yellow
Prompt: One factor is asked
Participant’s answer: Orange
REFERENCES


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