Diversifying Psychometric Tools for Intelligence Assessment and Screening in Latin America

by

Emily C. Duggan
Bachelor of Arts, Boston University, 2009
Master of Science, University of Victoria, 2014

A Dissertation Submitted in Partial Fulfillment
of the Requirements for the Degree of

DOCTOR OF PHILOSOPHY

In the Department of Psychology

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Abstract

Objective: Cultural neuropsychologists face barriers such as access to culturally appropriate psychometric instruments and norms. Further, three commonly encountered dilemmas in cultural neuropsychology include the following questions: (1) How do psychologists determine the best normative data to use for a given assessment scenario? (2) Do measures and models developed with North American samples also work in adaptations of instruments used with cross-cultural samples? (3) How can alternative and cost-effective measures be developed to meet the need for additional assessment tools? In response to these dilemmas, this dissertation consists of three papers aimed at developing Latinx and cultural neuropsychology psychometric resources for one of the most common cultural assessment scenarios: intelligence assessment amongst Spanish-speaking individuals using the Wechsler Adult Intelligence Scale – Fourth Edition (WAIS-IV). **Chapter 1.** A sample of 305 highly educated Colombian corporate executives completed the WAIS-IV. Data were scored using norms from Colombia, Chile, Mexico, Spain, United States, and Canada and scores were compared using ANOVA. Additionally, a comparative sociodemographic framework was established to contextualize our sample to the standardization samples and populations of the six countries. **Chapter 2.** Accumulating evidence indicates the original factor structures published in the Wechsler Intelligence Scales may not best describe the data captured by these tests, and instead supports a five factor Cattell-Horn-Carroll (CHC) model over a four factor Wechsler model, and a bifactor model over a higher-order model. Confirmatory factor analysis and structural equation modeling was used to evaluate factor structure of the Chilean-WAIS-IV (Wechsler, 2013) normative sample (ages 18-60; N=672) to better understand its psychometrics and to contribute to much needed cross-cultural study of alternative WAIS-IV factor models. Results marginally favored CHC and bifactor models but provided strong support for higher-order and Wechsler model variants as well, pointing to the need of further theoretical, methodological, clinical, and cross-cultural research. **Chapter 3.** The recent publication of the Chilean adaptation of the WAIS-IV has contributed to ongoing efforts to provide more psychometric instruments culturally appropriate for regions in South America. While not all assessment situations necessitate administration of the full WAIS and calculation of a full-scale intelligence quotient (FSIQ), there is virtually no published research on WAIS-IV short forms for estimating IQ in Latin America. This study used a rigorous series of methods (adapted from Smith et al., 2000) to develop robust estimated IQ short forms, aligned with Wechsler and CHC models, using the Chilean WAIS-IV standardization data (ages 18-90; N=887). Linear scaling was used to produce normative tables for the 28 best two-, three-, four-, and five subtest short forms of the Chilean WAIS-IV. **Discussion.** Together, the three papers of this dissertation provide psychometric guidance and resources not only for Latin American neuropsychologists in the area of intelligence assessment, but also more broadly for all cultural neuropsychology researchers and clinicians.

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Acknowledgements

Standardization data from the Wechsler Adult Intelligence Scale – Fourth Edition Chilean edition (WAIS-IV), Copyright © 2013 NCS Pearson, Inc. Used with permission per Dr. Ricardo Rosas, Pontificia Universidad Católica de Chile. All rights reserved. Data provided with permission from Tecnoquímicas, S. A. I gratefully thank the Vanier Canada Graduate Scholarship and the Natural Sciences and Engineering Research Council of Canada for their financial support of my research. Additionally, this work was supported by Mitacs through the Mitacs Globalink Partnership Award-Abroad Program. I am also appreciative of the contributions of my colleagues Cilia Carolina Loaiza A., Lina Marcela Awakon L., Isabella Irurita P., Diana Aribel Guzmán, and Angela Marcela Garcia at Tecnoquímicas, S. A., Dr. Elena Pérez-Hernández at the Universidad Autónoma de Madrid, Yaira Chamorro-Diaz and Pablo Álvarez-Tostado at the Neurosciences Institute, Universidad de Guadalajara, and Victor Skrzypczynski and Chloe Swabey at the University of Victoria. Muchas gracias.

Dedication

To Anne Anastasi, Martha Denckla, Edith Kaplan, Muriel Deutsch Lezak, Brenda Milner, Mónica Rosselli, Esther Strauss, and all the women who have paved the way. Thank you.

Prologue

This dissertation consists of three related, but distinct manuscripts designed to expand the selection of robust psychometric tools for the assessment and screening of intelligence in Latin America. This work stems from my experiences while doing a research consulting internship for three months in Colombia. The psychologists and researchers I came to know there were eager to have more theoretically and empirically supported assessment resources, developed specifically for the populations they work with, and adaptive to the unique problems they regularly encounter. Through my exposure to Latin American psychometrics, I came to better appreciate the disparity between the amount of quality assessment resources that exist for English-speaking populations (particularly in the United States and Europe) versus for non-English-speaking populations. In facing this “cultural neuropsychology gap” with my colleagues, I was driven to ask what could be done *now* to start pragmatically addressing this problem. The three manuscripts forming this dissertation represent my ideas and efforts to make a small contribution in helping narrow that gap.

Historically, intelligence assessment lies at the heart of all contemporary psychometrics and remains one of the most widely evaluated constructs within the fields of psychology and neuropsychology, with the Wechsler Intelligence Scales among the most popular set of intelligence assessment instruments around the world. Thus, I decided to focus the scope of this research to intelligence assessment in Latin America using the Wechsler Intelligences Scales. The first paper provides a clinical decision-making framework in a cross-cultural assessment situation and demonstrates the effects of applying different sets of intelligence norms. The second paper empirically evaluates the replicability of alternate factor structure models that have been well validated in United States and European populations (including the Cattell-Horn-Carroll theory of intelligence). The third paper derives intelligence screening tools aimed at meeting the urgent need for additional assessment instruments in Latin America.

Together, these papers form a cohesive collection of empirical research related to helping fill the cultural neuropsychological assessment gap, particularly for Latinx populations. Of note, the first chapter uses the term Hispanic instead of Latinx, which is favored in rest of the manuscript and is a more accurate term reflecting the sociocultural contexts discussed herein. This shift in terminology corresponds to the chronology of the manuscripts as well as broader ongoing sociocultural change that has become more evident to me through the writing of this dissertation. The three chapters are inter-related in that their findings inform each other, but they are largely standalone research contributions (written for individual submissions for publication), each with specific aims, methods, conclusions, and limitations. As a result, the autonomous nature of the articles introduces some redundancies within the dissertation including the reviewed literature and, to a lesser extent, the individual discussions and conclusions provided. However, the manuscripts are written to complement one another and to contribute to current and future research pertaining to the assessment of Latinx individuals in the Americas.

Chapter 1. Contributing Towards a Cultural Neuropsychology Assessment Decision-Making Framework: Comparison of WAIS-IV Norms from Colombia, Chile, Mexico, Spain, United States, and Canada*

*Manuscript published under the following citation: Duggan, E. C., Awakon, L. M., Loaiza, C. C., & Garcia-Barrera, M. A. (2018). Contributing towards a cultural neuropsychology assessment decision-making framework: Comparison of WAIS-IV norms from Colombia, Chile, Mexico, Spain, United States, and Canada. *Archives of Clinical Neuropsychology, online first.* doi:10.1093/arclin/acy074

All work in this chapter was conceived of and carried out by me, with the exception of some contributions colleagues who assisted with aspects of data collection and management (see acknowledgments) and the critical feedback incorporated into the execution of some analyses and the writing of this manuscript by Mauricio Garcia-Barrera and my other committee members.

Abstract

Objective: Test and normative data selection in cross-cultural neuropsychology remain a complex issue. Despite growing awareness, more studies and instruments are needed to adequately address the impact of cultural factors, such as quantity and quality of education. In this study, we examine the interpretive effects of applying six relevant WAIS-IV norms to a Colombian sample. **Method:** A sample of 305 highly educated Colombian corporate executives completed the WAIS-IV. Data were scored using norms from Colombia, Chile, Mexico, Spain, United States, and Canada and scores were compared using ANOVA. Additionally, a comparative sociodemographic framework was established to contextualize our sample to the standardization samples and populations of the six countries. **Results:** Colombian and Chilean norms yielded systematically similar FSIQ/Index scores (mean range=117-121), while incrementally lower scores were found with norms from Mexico (-3-9 points), Spain (-3-11 points), United States (-8-13 points), and Canada (-11-18 points). Verbal scores differed, with highest scores obtained with Mexican and Spanish norms. Working memory and processing speed scores had the lowest score agreement across norms. **Conclusions:** Although the Chilean norms are more frequently used in Colombia, the recently developed Colombian norms appear optimal for our sample; the scores do not have meaningful differences with those obtained with Chilean norms and offer local population representation fidelity. Mexican, Spanish, United States, and Canadian norms underestimated WAIS-IV scores and distorted the sample's score distribution. Finally, verbal scores highlight potential education representation within Spanish and Mexican norms, while working memory and processing speed scores suggest cultural nuances likely captured within different norms.

Keywords: Intelligence; Assessment; Cross-cultural/minority; Norms/normative studies

Introduction

With increasing globalization, there has been growing concern amongst neuropsychologists regarding best cross-cultural assessment practices (Cagigas & Manly, 2014; Hambleton, Merenda, & Spielberger, 2005). One area of rapid development has been the field of Hispanic neuropsychology, which has not only been tied to changing immigration patterns, but also professional and cultural collaborations throughout North and Latin America (Puente & Ardila, 2000; Puente, Perez-Garcia, Vilar Lopex, Hidalgo-Ruzzante, & Fasfous, 2013). A number of ethical and practice guidelines and standards providing recommendations for assessment practices with culturally diverse populations have been put forth (American Educational Research Association, American Psychological Association [APA], & National Council on Measurement in Education, 2014; APA, 2003, 2017; Clauss-Ehlers, Chiriboga, Hunter, & Roysircar, 2019; see also Suzuki & Ponterotto, 2008; Uzzell, Ponton, Ardila, 2007) and the professional and ethical obligation to develop competency in cross-cultural assessment, including consideration of cultural and sociodemographic factors and use of appropriate norms, has been widely discussed in the literature (Boone, Victor, Wen, Razani, & Pontón, 2007; Brickman, Cabo, & Manly, 2006; Judd et al., 2009; Rivera Mindt, Byrd, Saez, & Manly, 2010). Despite this, a recent study found that almost 40% of psychologists surveyed do not use any multicultural assessment theories or frameworks in their assessments, and many clinicians omit basic strategies such as consulting the literature on a client's cultural background (Edwards, Burkard, Adams, & Newcomb, 2017). Further, a survey of neuropsychologists who provide services to Hispanic populations found that most are not adequately prepared and lack the appropriate tools to work with this population (Echemendia & Harris, 2004; Echemendia, Harris, Congett, Diaz, & Puente, 1997). These results speak to potential barriers in translating cross-cultural assessment theory into day-to-day practice.

Several barriers appear to affect the implementation of effective cross-cultural assessment. First, education and supervision appear to be a significant factor. Edwards et al. (2017) found that younger clinicians tend to incorporate more multicultural assessment approaches in their work, which they suggest is likely a function of changing accreditation standards. Another barrier may simply be a scarcity of assessment resources to put cross-cultural information to meaningful use. In fact, North American neuropsychologists report lack of appropriate normative data as a leading barrier to multicultural assessment (Elbulok-Charcape, Rabin, Spadaccini, & Barr, 2014). Similarly, Latin American and Spanish neuropsychologists report lack of norms for their respective countries as a top barrier affecting their neuropsychological assessments (Arango-Lasprilla, Stevens, Morlett Paredes, Ardila, & Rivera, 2017; Fernandez, Ferreres, Morlett-Paredes, Rivera, & Arango-Lasprilla, 2016; Fonseca-Aguilar et al., 2015; Olabarrieta-Landa et al., 2016). Further, when conducting culturally informed assessments, clinicians routinely encounter scenarios that fall within the gray-area of ethical standards and practice guidelines and psychometric resources often force clinicians to make assumptions or prioritize some sociodemographic variables over others (e.g., age, sex, education, primary language, native language, country of origin, and country of residence). These factors likely add to the self-reports of clinicians feeling ill-equipped to adequately address complexity of these cases (Echemendia et al. 1997; Edwards et al., 2017; Elbulok-Charcape et al., 2014; Fernandez et al., 2016; Fonseca-Aguilar et al., 2015; Olabarrieta-Landa et al., 2016).

Sources of Cross-Cultural Differences and Hispanic Neuropsychology

Despite the challenges associated with cross-cultural assessment, many resources are available to help guide clinicians in the use of multicultural frameworks and understanding which factors may be more relevant than others (Dana, 2005; Hays, 2016; Ridley, Tracy, Pruitt-Stephens, Wimsatt, & Beard, 2008). Overall, education is a key sociodemographic variable that contributes to neuropsychological performance and normative data differences (Lezak, Howieson, Bigler, & Tranel, 2012; Lynn, Fuerst, & Kirkegaard, 2018). Within Hispanic neuropsychology, substantial educational effects on neuropsychological test performance among English and Spanish-speaking individuals have been well documented in the literature (Abad, Sorrel, Roman, & Colomn, 2016; Acevedo et al., 2007; Ardila, 1998; Ardila, Ostrosky-Solís, Rosselli, & Gómez, 2000; Cavé, 2008; Pontón & Ardila, 1999; Renteria, Li, & Pliskin, 2008). For example, in a sample of Spanish-speaking foreign-raised older adults living in the United States, education was the most influential sociodemographic variable on neuropsychological test scores. Specifically, Acevedo, Loewenstein, Agrón, and Duara (2007) report lower levels of education (3-8 years) were associated with significantly worse test performance. Comparatively, age, gender, age of arrival in the United States, proportion of lifetime residence in the United States, acculturation, and depression had limited effects (Acevedo et al., 2007). Quality of education—known to vary greatly between and within countries— is also associated with neuropsychological test performance, such that poorer education results in lower test scores (Llorente, 2007; Puente et al., 2013). In a study of young adults in Chile, there were no Wechsler Adult Intelligence Scale—Fourth Edition (WAIS-IV; Wechsler, 2013) differences among rural residents with basic, medium, or high levels of education, nor were there differences between rural and urban residents with basic education. However, urban residents with medium or higher levels of education had better WAIS-IV performance across indices and full-scale intelligence quotient (FSIQ; Fuica et al., 2014).

In addition to education, other cultural influences and values substantially impact neuropsychological assessment (Ardila, 2005). For instance, at least two studies have found no effects of education on neuropsychological test performance in low education (Guerroer-Berroa et al., 2016) and education-matched samples (LaRue, Romano, Ortiz, Liang, & Lindeman, 1999) from different Latin American regions. Although a growing literature investigates neuropsychological test performance among Spanish speaking immigrants in the United States, we must be aware of heterogeneity and United States Spanish-speaking immigrants may not be representative of broader cultural groups (Llorente, Pontón, Taussig, & Satz, 1999; Pontón & Ardila, 1999). As such, determining which norms to apply within the multicultural assessment context may not always be an easy decision. For example, comparison of a highly-educated individual in a Spanish-speaking country to a low education normative group from the same country may not be appropriate. Similarly, comparison of a Spanish-speaking individual from one country to Spanish-speaking individuals from another country may also be inappropriate (Buré-Reyes et al., 2013). All together, these findings underscore the importance of cross-cultural research aimed at improving testing practice.

Cross-Cultural Intelligence Assessment and Hispanic Neuropsychology

One of the most widely used assessment instruments in the world is the Wechsler Adult Intelligence Scale (WAIS; Rabin, Paolillo, & Barr, 2016; Ready & Barnett Veague, 2014). Now in its fourth edition, the WAIS-IV (Wechsler, 2008b, 2008c) has been adapted into more than 25 different cultural versions (Pearson Clinical, 2019). In general, the WAIS-IV family of instruments has been noted to feature many psychometric improvements over prior versions of the WAIS, including improved factor analytic evidence and scores but less affected by ethnicity (but more by education) than the WAIS-III (Weiss, Saklofske, Coalson, & Raiford, 2010; Whipple Drozdick, Wahlstrom, Zhu, & Weiss, 2012). Given the prolific cross-cultural development of the WAIS and other assessment instruments, understanding sociodemographic normative sample differences is a critical component of cross-cultural assessment practices. While selection of incongruous norms affects accuracy and applicability (Bender, García, & Barr, 2010), clinicians recognize that a specific set of norms may not best reflect a person's cultural demographics (e.g., amount and quality of education), despite nationality and recommendations from the APA (2017). This issue has been widely discussed in the context of the WAIS-III and IV in South Africa, where it has been debated if it would be more suitable to use United States or United Kingdom norms for the minority of individuals with significant educational advantage over the general population (e.g., those with access to private, European or North American style education; Shuttleworth-Edwards, 2016; Shuttleworth-Edwards, 2017; Shuttleworth-Edwards, Gaylard, & Radloff, 2013; Shuttleworth-Edwards, Kemp, Rust, Muirhead, Hartman, & Radloff, 2004; Suchy, 2016; Sunderaraman, Zahodne, &

Manly; 2016; Taylor, 2016; Wicherts, 2016). A lack of consensus on how to deal with these gray-areas involving so-called educationally or culturally advantaged individuals speaks to the difficulty surrounding decision-making within cross-cultural neuropsychological assessment and the likely complex and multifactorial approach it will take to arrive at a solution.

Unfortunately, studies investigating the interpretation effects of applying different WAIS-IV norms to cross-cultural populations are surprisingly uncommon, with a large proportion relating to the use of the WAIS-IV in South Africa, and nearly all the rest comparing English versions of the WAIS-IV with one another (e.g., United States and Canada; Wechsler, 2008d; 2008e). Overall, this research has supported the generality of the construct validity of the WAIS-IV across United States and Canadian samples, but also reiterates the importance of local norms (Bowden, Saklofske, & Weiss, 2011; Harrison, Armstrong, Harrison, Lange, & Iverson, 2014; Iverson, Lange, Viljoen, 2006). For example, scores on the WAIS-III and WAIS-IV are higher in the Canadian standardization sample than the United States sample (Bowden et al., 2008; Bowden et al., 2011). Comparatively, the Canadian WAIS-IV sample has a mean FSIQ (104.5) slightly higher than the British WAIS-IV sample (102.5), both of which are slightly higher than the United States WAIS-IV sample (100; Dutton & Lynn, 2014). These differences are thought to represent sociocultural effects, rather than true IQ differences. For example, cultural factors, such as education differences and test-taking attitudes appear to drive American and European (British, Finnish, French, German, and Spanish) cross-national test profile differences on the WAIS-R and III (Roivainen, 2010).

The largest body of research investigating the use of the WAIS in Spanish-speaking populations has centered around the earlier third edition, the WAIS-III (Wechsler, 1997) and three of its Spanish versions, including those from Puerto Rico (EIWA-II-PR; Wechsler, 2008a), Spain (WAIS-III-S; Wechsler, 2001), and Mexico (WAIS-III-M; Wechsler, 2003). Overall, research has consistently shown the English-version of the WAIS-III risks overestimating deficits and is not adequately standardized for use in

Spanish-speaking populations. Further, the Spanish-language versions of the WAIS-III generally risk underestimating deficits and have validity concerns (Funes, Hernandez Rodriquez, & Lopez, 2016; Maldonado, & Geisinger, 2005; Renteria, et al., 2008; Thaler & Jones-Forrester, 2013). In general, practitioners and researchers tend to view the WAIS-III and its corresponding Spanish-language versions as historically informative to cross-cultural assessment; however, they caution against its continued use (Llorente, 2007). Current Spanish-versions of the WAIS-IV include those for Spain (Wechsler, 2012a), Mexico (Wechsler, 2014a), Chile (Wechsler, 2013), and just recently Colombia (Wechsler, 2016). Aside from the validation studies for these instruments, very little research has examined the use of the WAIS-IV in Spanish-speaking populations, particularly outside of North America, and no studies to our knowledge have directly compared the interpretive effects of Spanish versions of the WAIS-IV with other Spanish and English versions of the WAIS-IV.

Additional challenges in cross-cultural and Hispanic neuropsychology are associated with the implementation of new assessment measures like the many country-adapted versions of the WAIS-IV. First, it takes time to amass an evidence-base for an instrument. For example, since the Colombia version of the WAIS-IV is so new, it has not yet been widely implemented in clinical work or research, and limited research has published on the use of the WAIS-IV in Colombian samples. In the absence of a Colombian WAIS-IV over the last several years, psychologists have relied on the Chilean adaptation of the WAIS-IV (Wechsler, 2013), which was then considered the best and most appropriate intelligence assessment instrument available. In these scenarios, psychologists need to understand the differences across instruments. For instance, how might switching from the Chilean version to the Colombian version affect WAIS-IV scores and their interpretation for past and future clients?

Managing socioeconomic differences unique to countries is another challenge. Like the difficulties facing South African psychologists, Colombian psychologists also have the difficulty of determining how to factor in cultural advantage found in select minority of Colombians (i.e., individuals with disproportionately high socioeconomic resources, including access to private compulsory education that differs substantially from public compulsory education). In this context, Colombian neuropsychologists may be tempted to use alternate norms for this select minority, but there are no resources available to help them understand the norm differences between the Colombian WAIS-IV and other Spanish-speaking nations in North America (i.e., the Mexican WAIS-IV; Wechsler, 2014a) and in Europe (i.e., the Spanish WAIS-IV; Wechsler, 2012a), as well as widely used and researched English versions including the United States WAIS-IV (Wechsler, 2008b) and the Canadian WAIS-IV (Wechsler, 2008d).

Current Study

The present study used WAIS-IV data from a Colombian sample of highly-educated and high-achieving adults to investigate several key issues pertaining to norm selection within cross-cultural and Hispanic neuropsychology. Specifically, the interpretive effects of applying different WAIS-IV norms potentially applicable to this culturally advantaged population were compared. Based on multicultural assessment guidelines (American Educational Research Association, American Psychological Association [APA], & National Council on Measurement in Education, 2014; APA, 2003, 2017), a study-appropriate framework was established and key sociodemographic data and resources from the literature were compiled. Thus, this framework was used to contextualize results. Overall, the two main goals of this study were to generate practical resources for clinicians working in the field of Hispanic neuropsychology, and to contribute to research designed to help bridge the gap between theory and practice within cross-cultural neuropsychology more broadly.

Methods

In determining the appropriateness of a given set of norms for an individual or group, first a context must be established (Hays, 2016). That is, how well is the present sample of Colombian executives represented by their country-specific norms or potentially other relevant normative samples? To address this issue, multiple levels of information, as follows, were integrated to provide a functional cultural contextualization.

Considering the Colombian Context

Colombia is the third largest Spanish-speaking country in the world, behind Mexico and the United States (Instituto Cervantes, 2015), and is comprised of immense ethnic and cultural diversity. While the development of Colombia and its citizens has been greatly affected by conflict, particularly from the 1960s to the 1990s, the country is now characterized by improved political stability and increasing economic growth. Clinicians working with individuals from Colombia, therefore, must be aware that Colombians can differ drastically in terms of quantity and quality of education received, socioeconomic status (SES), and the broader sociopolitical climate of the country during their upbringing and development (cf. LeGrand, 2003 for a brief overview and LaRosa & Mejía, 2017 for a more comprehensive overview of pertinent issues and factors to consider). Although beyond the context of this paper, it is worth noting that substantial effort was put into developing awareness and understanding of these factors and considering the broader Colombian context throughout this study.

Participants

Data was collected from a sample of 305 professionals occupying executive positions within a large multinational corporation headquartered in Cali, Colombia. Approximately 65% of the participants currently hold strategic/tactic positions within the corporation, while the remaining participants are a select group of trainees who aspire to occupy strategic/tactic positions in the future. Individuals hired into these positions typically occupy higher socioeconomic levels and have received high quality education through at least the post-secondary level (e.g., private schools modeled on North American or European systems). History of significant neurologic or psychiatric conditions is unknown and not within the corporation’s purview; however, given the functional status of these participants, any substantial presence neurologic or psychiatric history affecting the results and interpretation of this study is unlikely. All data was collected under a built-in contractual agreement with their employees that includes stipulations for regular internal assessments. The purpose of the company's internal assessments is to identify strengths and weaknesses to inform programs aimed at strengthening the cognitive and behavioral conditions of company professionals. In this context, employees were invited to participate in our study and a written informed consent for the use of their deidentified data in this study was obtained from all participants and approved by the Human Research Ethics Board at the University of Victoria (Protocol Number 16-244). All participants are Colombian natives, with Spanish as their first and primary language. A demographic summary of the participants is provided in Table 1.1.

Measures and Establishing a Comparative Framework

All participants were administered the entire (core and supplementary) WAIS-IV (Wechsler, 2013) by a team of trained, native Spanish-speaking administrators, in accordance with standardized practice. Given the aims of this paper to investigate the interpretive effects of applying WAIS-IV norms that could potentially be applicable to our atypical Colombian sample, we chose six sets of WAIS-IV norms to use in our research. First, we chose the Colombian WAIS-IV norms, as per APA guidelines, these would be the most applicable to our sample. Second, we chose the Chilean WAIS-IV norms, because these are the norms that have been used throughout Colombia prior to the recent release of the Colombian WAIS-IV. Additionally, Chile and Colombia share many sociocultural, economic, and historic similarities. Next, we chose two additional sets of norms derived from Spanish-speaking populations, one from North America – the Mexican WAIS-IV, and one from Europe – the Spanish WAIS-IV. In theory, these normative groups could encompass some cultural and educational aspects unique to our sample of Colombian executives. Finally, we chose two sets of norms derived from primarily English-speaking populations: the United States WAIS-IV and Canadian WAIS-IV. These normative groups were selected based on their potential educational similarities with our sample. Additionally, since most of the literature comparing interpretive effects of applying different sets of WAIS norms has used the

United States and Canadian norms, including them in our present research provides a good benchmark to help compare our research to the current literature. Descriptive information for these normative samples is briefly summarized below and in detail in Table 1.4.

The (United States) WAIS-IV. The WAIS-IV (Wechsler, 2008b; 2008c) is the most widely used intelligence assessment instrument for individuals 16-90 years old and is the mother instrument for all other cultural adaptations of the WAIS-IV. It includes 10 core and 5 supplemental subtests and yields a full-scale IQ (FSIQ) and 4 index scores (verbal comprehension index, VCI; perceptual reasoning index, PRI; working memory index, WMI, and processing speed index, PSI). The WAIS-IV was standardized with a sample 2,200 individuals selected to represent the 2005 United States Census. It was stratified across 13 age-bands along with sex, ethnicity (white, African American, Hispanic, Asian, or “other”), education attainment of self (for ages 20-90) or parents (for ages 16-19; four levels ranging from no education to tertiary education), and geographic region (North East, Mid-West, South, and West).

The Canadian WAIS-IV. The Canadian version of the WAIS-IV (Wechsler, 2008d; 2008e) was adapted from the original WAIS-IV (Wechsler, 2008b) and it includes the same subtests, items, and score structure with only minor cultural adaptations in item content/scoring. It was standardized with a Canadian, English-speaking sample (ages 16-90) of 668 individuals selected to represent the 2006 Canadian Census. Like the original WAIS-IV, the sample was stratified across 13 age-bands along with age, sex, ethnicity (Caucasian, Asian, First Nations, and “other”), education of self (for ages 20-90) or parents (for ages 16-19; four levels ranging from ‘incomplete secondary education’ to ‘university degree or greater’), and geographic region (West, Central, and East; Wechsler, 2008d).

The Spanish WAIS-IV. The Spanish version of the WAIS-IV (Wechsler, 2012a, 2012b) was the first published Spanish-language adaptation of the WAIS-IV (Wechsler, 2008b). Like the WAIS-IV, it includes the same subtests, items, and score structure as the WAIS-IV with only minor item content/scoring adaptations to adjust for language and culture. It was standardized in a representative sample of 1,002

Spanish-speaking Spaniards ages 16-90 years stratified across 10 age-bands based on the Spanish census. Norms were also stratified based on educational attainment level (ranging from “no education” to “tertiary education”) and community characteristic (i.e., urban, suburban, or rural).

The Mexican WAIS-IV. The Mexican version of the WAIS-IV (Wechsler, 2014a) is an adaptation of the Spanish WAIS-IV (Wechsler, 2012a) for the Mexican population. It includes the same subtests, items, and score structure as the Spanish WAIS-IV (and thus, the WAIS-IV) with only minor cultural adaptations to item content/scoring. The Mexican WAIS-IV standardization sample included 1,450 Mexican, Spanish-speaking individuals, ages 16-90 years, reflective of the Mexican population according to the 2010 Mexican census (INEGI, 2010). The normative sample was stratified across 13 age-bands, geographic region, and education; however, the technical manual provides little education information about the normative sample.

The Chilean WAIS-IV. The Chilean version of the WAIS-IV (Wechsler, 2013) is a Chilean adaptation of the Spanish WAIS-IV (Wechsler, 2012a). It includes the same subtests, items, and score structure as the Spanish WAIS-IV (and thus, WAIS-IV) with only minor cultural adaptations to item content/scoring. It was standardized in a sample of 887 Chilean, Spanish-speaking individuals representative of the general Chilean population (Census information not provided) and stratified by 13 age-bands as well as sex, geographic region, and an education proxy variable. More specifically, the sample was stratified into three socioeconomic levels based on the country’s socioeconomic stratification systems ranging from 1 to 6 (strata 1-2=low, strata 3-4=middle, strata 5-6=high). Using this system and its high correlation with educational attainment, education was approximated with socioeconomic level. Thus, low socioeconomic status approximately comprises individuals with ≤8 years of formal education, middle socioeconomic status comprises mostly individuals with 9-17 years of formal education (advanced basic education and some technical study), and high socioeconomic status comprises mainly individuals with a completed undergraduate degree or more (approximately ≥18 years of formal education; Rosas et al., 2014).

The Colombian WAIS-IV. As with the Mexican and Chilean versions of the WAIS-IV, the Colombian WAIS-IV (Wechsler, 2016) is a Colombian adaptation of the Spanish WAIS-IV (Wechsler, 2012a), that includes the same subtests, items, and score structure as the WAIS-IV-Es (and thus, the WAIS-IV) with only minor cultural adaptations to item content/scoring. It was standardized with a Colombian, Spanish-speaking sample of 156 individuals purportedly representative of the general Colombian population (Census information not provided) and stratified by 13 age-bands along with sex, geographic region, and the same socioeconomic-education proxy variable as in the Chilean sample based on the identical Colombian socioeconomic strata system (R. Rosas, personal communication, June 1, 2017). Of note, no technical manual for the Colombian WAIS-IV or any other related research has been published to the authors' knowledge as of the date of this paper.

Analyses

Descriptive statistics for the present sample of 305 Colombian executives were calculated, including age, sex, and education. In Colombia, ethnicity is not a construct readily discussed or measured; therefore, participants' ethnicity was not surveyed as it would not be a meaningful or accurate question to ask. Qualitative ethnicity information, however, is reported in our results (cf. Cadavid-Ruiz, del Río, Egido, & Gallindo, 2016 and DANE, 2007 for an example of how demographic variables are typically treated in a Colombian sample). Sociodemographic characteristics for the six WAIS-IV normative groups were compiled from their manual and technical documentation (Rosas et al., 2014; Wechsler, 2008b, 2008c, 2008d, 2008e, 2012a, 2012b, 2013, 2014, 2016). The most up-to-date country level sociodemographics available were compiled from multiple high quality population statistics recourses (Instituto Cervantes, 2016; UNESCO Institute for Statistics, 2012, 2017; World Bank, 2017, World Economic Forum, 2017-2018). All sociodemographics were converted into the same scale or units to facilitate comparisons. For example, all educational data is reported using the International Standard Classification of Education (ISCED; UNESCO Institute for Statistics, 2012). Sample-level sociodemographics are reported in Table 1.1, country-level sociodemographics are reported in Tables 1.2 and 1.3, and WAIS-level sociodemographics are reported in Table 1.4.

WAIS-IV scores including subtest scaled scores, indices (VCI, PRI, WMI, and PSI) and FSIQ for each of the 305 Colombian executives were calculated six times, using the selected country norms from Colombia, Chile, Mexico, Spain, United States, and Canada. This yielded six sets of scores for each participant, which were then compared using repeated measures analysis of variance (ANOVA). In cases in which the assumption of sphericity was violated, the Greenhouse-Geisser correction was used and multivariate tests (general linear model) were reported. Significance was set at p <.05 and effect sizes for overall comparisons are reported using partial eta squared (η^2). All analyses were followed up with post-hoc comparisons that included simple within-subjects contrasts of the effect of Colombian against the other five select country norms as well as comprehensive pairwise comparisons (all norms against all other norms based on estimated marginal means), adjusted using the Bonferroni correction. Effect sizes (r) for simple within-subjects contrasts between scores obtained with Colombian norms and the other five select countries ($r = \sqrt{} \, (F(1,df_R)/ \, (F(1,df_R)+df_R))$) are also reported, with effect sizes greater than 0.50 classified as high, 0.30 to 0.49 as medium, and less than 0.30 as low (Cohen 1988). Note that effect sizes could only be calculated for comparisons against Colombian norms due to the selected post-hoc analyses which protectively restrict the numbers of statistical tests computed. Percent agreement between scores calculated with the Colombian norms and the five other normative systems (Chile, Mexico, Spain, United States, and Canada) was calculated using three criteria: (1) percent within 1/3 of a standard deviation (*SD*; i.e., ± 5 points for FSIQ/Index scores and 1 point for subtest scores), (2) percent within the same descriptive classification level (i.e., ranging from very low to very superior for FSIQ/Index scores, and low-to-high for subtest scores; Wechsler, 2008b), and (3) percent within 1/3 *SD* *or* within one classification level. All statistics were calculated using Microsoft Excel and SPSS Statistics Version 24 (IBM, 2017).

Results

Sample Characteristics

As reported in Table 1.1, the sample comprised a nearly even amount of men and women (52% and 48%, respectively) with a mean age of 34 years. Although the age range is wide (ranging from 20 to 68), 44% are between ages 20-30 and 53% are between the ages of 30 and 55. Using the ISCED, just over half of the sample has some graduate education (54%) and the remainder has education falling between completed secondary school and a Bachelor's degree (46%). Only one individual (0.33%) completed compulsory education. Data on education quality were unavailable; however, many individuals in Colombia who pursue higher education traditionally come from higher socioeconomic levels and based on internal company information, approximate SES for most of the sample likely falls between SES strata 3-6 (i.e., middle to high SES). Although ethnicity is not a highly relevant construct to measure according to North American perceptions, we can report general information. According to the most recent Colombian census, the three primary ethnic categories are "no-ethnicity" (including white and mestizo, 86%), afrocolombian (11%), and indigenous (3%; DANE, 2007). In Valle del Cauca, the region where our sample is situated, ethnic group representation is similar: 72% no ethnicity, 27% afrocolombian, and 0.6% indigenous (DANE, 2007). Qualitatively, most our sample would fall into the "no-ethnicity" category, mostly identifying as white or mestizo.

Sample Characteristics in Relation to Country-Specific Sociodemographic Information

Tables 1.2 and 1.3 provide relevant country-level education and socioeconomic statistics for Colombia, Chile, Mexico, Spain, United States, and Canada. The World Bank (2017) estimates that on average, Colombian adults have 9.35 years of education. Further, according to the UNESCO Institute for Statistics (2017) about 16.3% of the adult Colombian population has a bachelor's level of education, and

3.2% has a graduate education. Thus, overall, about 20% of Colombians have post-secondary education. Using this information to contextualize, we see that our sample of 305 executives has a relatively high level of education compared to the broader Colombian population, but not a level of education that is particularly uncommon (i.e., one-fifth of Colombians have post-secondary education and would meet basic corporate employment criteria for positions such as those occupied by our sample).

Comparing Colombia to other countries, we can see that Chile and Mexico have similar levels of mean education (10.35 years and 9.18 years, respectively), as well as rates of adults with post-secondary education (18% and 16%, respectively). This indicates that education attainment is similar for adults from Colombia, Chile, and Mexico. Comparing Colombia with Spain, average education in Spain is slightly higher (10.75 years) and Spanish adults with post-secondary education are about 1.5 times more frequent (29%). Colombian educational attainment is most different from that in the United States and Canada. Overall, United States and Canadian adults typically complete more years of school (13.24 years in the United States and 12.74 years in Canada). Further, compared with Colombians, post-secondary education is twice as common among Americans (42%) and three times as common among Canadians (60%). Although quality of education ranges between countries, it appears that access to high quality education in Colombia, Chile, and Mexico is not rare. Given the association between educational attainment and intelligence scores, these country-level demographics suggest that the Colombian, Chilean, and Mexican WAIS-IV standardization samples would have similar (but unique) patterns of scores, with the Spanish, United States, and Canadian WAIS-IV standardization samples having increasingly distinct score patterns.

Relating Sample and Country Sociodemographics to WAIS-Level Information

Age. Table 1.4 provides information on the demographic characteristics of the WAIS-IV normative samples from Colombia, Chile, Mexico, Spain, United States, and Canada. In terms of age, all samples were stratified across 13 age-bands, except for the Spanish sample, which used 10 age-bands (as reflected in Tables 1.4 as well as for our sample in Table 1.1). Our sample has almost no people in the lower- and upper-most age-bands; however, the sample is well distributed across the remaining groups. For the Colombian WAIS-IV standardization sample, all age-bands contained the same number of individuals. The Chilean, Mexican, Spanish, United States, Canadian samples were well-represented across the age-bands and based on census figures, though representation proportions were determined using varying methods. While difficult to make comparisons, the age range of our sample is adequately represented in each of the six WAIS-IV normative samples.

Education. WAIS-IV normative samples differed in terms of representation of education. In the Colombian and Chilean WAIS-IV samples, education was not measured directly, but instead approximated through a SES variable – economic stratification level (strata), ranging from 1 to 6, which is strongly associated with education attainment (Buchmann & Hannum, 2001). Thus, the Chilean and Colombian WAIS-IV research teams approximated education by approximating low SES individuals (strata 1-2) to have 8 years of education or less, medium SES individuals (strata 3-4) to have approximately 9-17 years of education, and high SES individuals (strata 5-6) to have more than 17 years of education. These normative samples were evenly distributed across the SES groups (i.e., 33% low, 33% medium, and 33% high). After converting all data into ISCED units where ISCED 0-3 = high school education or less and ISCED 4-8 = post-secondary education and beyond, the Colombian WAIS-IV standardization sample comprises 67% falling with ISCED 0-3 and 33% within ISCED 4-8. At the country level (Table 1.3), 80% of education rates fall within ISCED 0-3 and 20% within ISCED 4-8. The statistics are nearly identical for Chilean WAIS-IV and country level education rates: WAIS-IV ISCED 4-8 = 33% and country ISCED 4-8 = 18%. This suggests that higher levels of education (post-secondary and beyond) are overly represented in the Colombian and Chilean WAIS-IV standardization samples. Likewise, these figures indicate over representation of the education level (proxy socioeconomic level) of our sample within the Colombian and Chilean WAIS-IV standardization samples.

Little information for the Mexican WAIS-IV standardization sample beyond a census reference was provided (INEGI, 2010); however, of most people without compulsory education, most left school during the high school years (9-11 years of education total). Without the precise figure, it is not clear how well population rates of education in Mexico are represented by the Mexican WAIS-IV norms, or how well education rates within our sample may be reflected in the Mexican WAIS-IV norms, other than to say that very low rates of education are likely not overrepresented. At the population level, 83% fall within ISCED 0-3 and 16% within ISCED 4-8.

The Spanish WAIS-IV standardization sample was stratified on four levels: no education, primary education, secondary education, and tertiary education, with 90% of the sample having compulsory education or less (ISCED 0-3) and 9% with education beyond compulsory levels (ISCED 4-8). Education rates at the country level (Table 1.3) are markedly different, with 70% within ISCED 0-3 and 30% within ISCED 4-8. This indicates that population levels of higher education are potentially underrepresented within the Spanish WAIS-IV norms. Further, this information also suggests the education level of our sample is likely underrepresented within the Spanish WAIS-IV norms.

The United States and Canadian WAIS-IV samples were stratified based on four levels: incomplete compulsory education (11 years or less), complete compulsory education (high school degree/12 years), post-secondary education (some college/vocational school/13-15 years), and university degree (17 years or more). For both the United States and Canadian WAIS-IV normative samples, higher education (post-secondary and beyond) appears slightly overrepresented based on current population levels (Table 1.3): 53% United States norms versus 42% for the population and 67% Canadian norms versus 60% Canadian population. This information suggests the education level of our sample is well captured within the United States and Canadian WAIS-IV norms, but it also indicates that the quality of education being captured by these norms is notably different than that captured within the WAIS-IV norms for Colombia, Chile, Mexico, and Spain (combining information from Tables 1.2, 1.3, and 1.4).

Comparison of WAIS-IV Scores

Omnibus tests (ANOVA and Multivariate) for score differences when applying Colombian, Chilean, Mexican, Spanish, United States, and Canadian WAIS-IV norms to our sample are presented in Supplemental Table 1.1. All omnibus test results show that FSIQ, Index and subtest scores were significantly affected by the type of norms applied (Supplemental Table 1.1). Looking more closely at the differences, descriptive statistics, mean comparisons, and effect sizes when applying these six norms sets to our sample are presented for FSIQ and Index scores in Figure 1.1 and Table 1.5, and for subtest scores in Figure 1.2 and Table 1.6. Data supporting post-hoc comparisons are referenced in Figures 1.1-1.2 and Tables 1.5-1.6 and reported fully in Supplemental Table 1.2. Mean classification agreement between applying the six normative systems to our sample are reported in Table 1.5 (FSIQ and Index scores) and Table 1.6 (subtest scores) and shown in Figures 1.3 (FSIQ) and 1.4 (Index scores).

FSIQ and Index scores. Rounding to whole scores (Table 1.5), mean FSIQs ranged from 121 (Chilean norms) to 109 (Canadian norms), VCIs from 126 (Spanish norms) to 111 (Canadian norms), PRIs from 118 (Colombian norms) to 107 (Canadian norms), WMIs from 118 (Colombian/Chilean norms) to 100 (Canadian norms), and PSIs from 121 (Colombian norms) to 108 (Canadian norms). Overall, the highest mean FSIQ and Index scores (except for the VCI) were obtained using the Colombian and Chilean norms (less than one point difference, mean scores ranging between 117 and 121); the next highest scores resulted when using the Mexican norms (3-9 points lower), followed by Spanish norms (3-11 points lower), United States norms (8-13 points lower), and the lowest mean scores were obtained using Canadian norms (11-18 points lower). For the VCI highest mean scores were obtained using Mexican norms (7 points higher than Colombian norms) and the Spanish (4 points higher), followed by those obtained with Colombian (mean VCI=119), Chilean norms (1 point lower), United States (5 points lower), and then Canadian norms (8 points lower).

Although several mean values in Table 1.5 appear exceedingly close, nearly all are statistically different. All mean FSIQ and Index scores obtained using Chilean, Mexican, Spanish, United States, and Canadian norms are significantly different (p <.0005) except for the Colombian versus Chilean WMI. Additionally, nearly all corresponding effect sizes for the 25 comparisons were high (22=high, 1=medium [Colombia versus Spain FSIQ], and 2=low [Colombia versus Chile FSIQ and WMI]). This indicates statistical differences between the mean FSIQ and Index scores obtained with Colombian norms and those obtained with each of the other five norm samples (Chilean, Mexican, Spanish, United States, and Canadian).

While ANOVA and corresponding post-hoc testing restricts the number of tests that can and should be performed (i.e., all combinations of norms), some additional information is available through pairwise comparisons based on estimated marginal means. This information is comprehensively reported in Supplemental Table 1.2 and more easily visualized in Figure 1.1 (FSIQ and Index scores) and Figure 1.2 (subtests scores). Empty bars within charts indicate mean scores that are significantly different (p <.05) from other scores. For examples, all mean VCI and PSI scores differ from one another (i.e., Colombia VCI ≠ Chile VCI ≠ Mexico VCI ≠ Spain VCI ≠ United States VCI ≠ Canada VCI). Filled bars indicate mean scores that are the same as each other, but different from all other scores. For example, all mean FSIQs differ from one another except those obtained using norms from Mexico and Spain (Mexico FSIQ = Spain FSIQ ≠ Colombia FSIQ ≠ Chile FSIQ ≠ United States FSIQ ≠ Canada FSIQ). All PRI mean scores differ except those obtained with norms from Spain and Canada and all WMI scores differ except those obtained with norms from Colombia and Chile.

The interpretive differences of applying different norms was evaluated with percent agreement of scores calculated with Colombian norms against those calculated with Chilean, Mexican, Spanish, United States, and Canadian norms using three criteria: within 1/3 *SD*, within same classification level, and within 1/3 *SD or* same classification level. Comparing scores calculated with Colombian norms and Chilean norms showed an extremely high percentage of agreement. Nearly all FSIQ/Index scores calculated with Chilean norms fell within 1/3 *SD* of the scores calculated with Colombian norms (FSIQ=99%; VCI, PRI, WMI, and PSI=100%). A high proportion of Chilean scores also fell within the same classification level (FSIQ=97%, VCI=88%, PRI=100%, WMI=85%, and PSI=100%). When scores did not fall in the same classification level, they usually fell one classification lower (e.g., from high average to average), although there were some cases of scores falling one classification higher. Using the more inclusive criteria of 1/3 *SD or* same classification level, 100% of the Chilean and Colombian scores were in agreement.

Substantially more Mexican scores were within 1/3 *SD* of Colombian scores for FSIQ (82%) and VCI (78%) than for PRI (31%), WMI (21%), and PSI (17%). A similar, but less pronounced trend was also found for Mexican-Colombian classification level agreement (FSIQ=66%, VCI=64%, PRI=45%, WMI=46%, and PSI=32%). For scores not falling in the same classification level, FSIQ, PRI, WMI, and PSI usually were lower by one or two classification levels, but VCI scores were higher by one or two classification levels. Using the combined criterion, Mexican and Colombian agreement was 89% for FSIQ, 82% for VCI, 51% for PRI, 50% for WMI, and 33% for PSI.

There was a wide range of agreement between scores obtained with Spanish and Colombian norms. Only about half of FSIQ scores were within 1/3 SD of each other (57%), while all others were substantially less (VCI=35%, PRI=25%, WMI=19%, and PSI=4%). Classification agreement also ranged (FSIQ=63%, VCI=43%, PRI=30%, WMI=28%, and PSI=21%). FSIQ classification levels not in agreement were more commonly one level lower (27%) than higher (10%), and WMI and PSI classification levels not in agreement were always one or two levels lower (66% and 7% respectively for WMI and 75% and 12%, respectively, for PSI). VCI classification levels not in agreement, however, were always higher by one or two levels (53% and 4%, respectively), and PRI non-agreeing classification levels ranged widely from two levels lower (15% combined) to three levels higher (55% combined). Using the combined criterion, Spanish and Colombian score agreement was 76% for FSIQ, 54% for VCI, 50% for PRI, 36% for WMI, and 23% for PSI.

Agreement between scores obtained with United States and Colombian norms also ranged. Using the 1/3 *SD* criterion, agreement was 57% for FSIQ, 45% for VCI, 31% for PRI, 2% for WMI, and 15% for PSI. Classification level agreement was 41% for FSIQ, 52% for VCI, 39% for PRI, 10% for WMI, and 30% for PSI. For classification level scores non in agreement, they were almost always one or two classification levels lower (FSIQ=57%, VCI=44%, PRI=61%, WMI=90%, PSI=70%) with only a few scores falling in a classification one level higher (0.33%-5%). With the combined criterion, United States and Colombian score agreement was 74% for FSIQ, 59% for VCI, 48% for PRI, 11% for WMI, and 33% for PSI.

Scores obtained with Canadian and Colombian norms had the least agreement. Using the 1/3 *SD* criterion, VCI score agreed approximately a third of the time (32%), while all others had little agreement (FSIQ=12%, PRI=15%, WMI=0.33%, and PSI=2%). According to the classification level criterion, agreement was slightly higher, but overall still low (FSIQ=18%, VCI=40%, PRI=25%, WMI=2%, and PSI=13%). For classification level scores not in agreement, they were one or two levels lower for 82% of the FSIQ scores, 60% of VCI scores, 65% of PRI scores, 78% for PSI scores, and one to three levels lower for 98% of the WMI scores. Only a very small amount of non-agreeing VCI scores were higher (0.66%). Combining the agreement criterion, Canadian and Colombian score agreement was 21% for FSIQ, 50% for VCI, 29% for PRI, 2% for WMI, and 14% for PSI.

The broad impact of classification level score agreement across norms applied can be visualized in Figures 1.3 (FSIQ) and 4 (Index scores). Although this information is redundant with values reported in Table 1.5, presenting it visually adds the ability to more easily understand how the distribution of scores changes when applying different norms. Looking at Figures 1.3 and 1.4, the distribution of scores obtained with Colombian norms appears roughly normal. The distribution of classification scores obtained with Chilean norms is almost identical to the Colombian norms distribution for FSIQ, PRI and PSI, and reasonably close for VCI and WMI. The distribution shapes of scores obtained with Mexican, Spanish, United States, and Canadian scores, however, are markedly different, with proportions of the sample obtaining higher and lower scores than one another altered notably.

Subtest scores. At the subtest level (Table 1.6), there were no statistical differences between the mean scaled scores obtained using Colombian norms and Chilean norms; however, nearly all other mean scales scores differed from the Colombian norm scores, with 57 out of 60 having significant differences (p <.01), and only three with no differences (Colombia versus Mexico Vocabulary, United States Cancellation, and Canada Cancellation). Similarly, nearly all corresponding effect sizes were high (52/60 high, 3/60 medium [Colombia versus Mexico Information and Blocks, Colombia versus Spain Information], and 5/60 low [Colombia versus Mexico Vocabulary, Colombia versus United States Information and Cancellation, Colombia versus Canada Information and Cancellation]). Note that effect sizes for Colombia versus Chile subtests could not be computed since there were no differences. Overall, these results show systematic similarities between mean subtest scores obtained with Colombia and Chilean norms, but systematic differences between mean subtest scores obtained with Colombian and Mexican, Spanish, United States, and Canadian norms.

Looking at mean subtest scores, Figure 1.2 again simply illustrates how mean subtest scores obtained with Colombian and Chilean norms never differ in the study sample. Further, mean Vocabulary scores obtained with Mexican norms also do not differ from the Colombian and Chilean scores, and mean Cancellation scores obtained with United States and Canadian norms also do not differ from the Colombian and Chilean scores. In addition, Figure 1.2 shows that subtest means obtained with Mexican and United States norms are the same for Information, Matrix Reasoning, Figure Weights; subtest means obtained with Mexican and Spanish norms are the same for Comprehension and Cancellation;

and subtest means obtained with Spanish and Canadian norms are the same for Figure Weights. Overall, most of the mean subtest differences are 1-2 scaled score points from those obtained with Colombian norms, with only five of the 75 comparisons resulting in differences greater than 2.5 scaled score points.

Using the combined criterion (i.e., within 1/3 *SD or* same classification level), percent agreement was much higher on the subtest level (ranging from 31 to 100% across subtests and norms). Scores obtained with Chilean norms agreed 100% of the time. Mexican score agreement ranged from 84% (Cancellation) to 100% (Vocabulary). Spanish score agreement ranged from 68% (Coding) to 97% (Cancellation). United States score agreement ranged from to 48% (Digit Span) to 100% (Information and Cancellation). Canadian score agreement ranged from to 31% (Digit Span) to 99% (Information and Cancellation). Lowest rates of agreement for VCI subtests were 74% for Similarities (Spain), 74% for Vocabulary (Canada), 94% for Information (Spain), and 82% for Comprehension (Canada). Lowest rates of agreement for PRI subtests were 70% for Block Design (Spain), 73% for Matrix Reasoning (Spain and Canada), 80% for Visual Puzzles (Spain), 71% for Figure Weights (Spain), and 78% for Picture Completion (Canada). Lowest rates of agreement for WMI subtests were 31% for Digit Span (Canada), 66% for Arithmetic (Canada), and 54% for Letter-Number Sequencing. Lowest rates of agreement for PSI subtests were 71% for Symbol Search (Canada), 65% for Coding (Canada), and 84% Cancellation (Mexico).

Discussion

In the ideal assessment scenario, psychologists should identify and use the most appropriate tests and norms for a given situation (American Educational Research Association, et al., 2014; APA, 2003, 2017; Clauss-Ehlers, Chiriboga, Hunter, & Roysircar, 2019). However, as nations diversify, immigration and emigration patterns increase, and psychologists increasingly face complex issues calling for nuanced integration of cultural factors, the most appropriate course of action may not be easily determined (Byrne et al. 2009). This study examined one such cultural assessment scenario, in which a case could be made to use a variety of different norms for WAIS-IV data from a large sample of Colombian executives with a potential educational advantage over the general Colombian population. Given the rarity of resources for this type of cultural assessment decision making, this paper first developed resources to contextualize our sample against selected norm and population groups with relevant sociodemographic and cultural features (e.g., language, socioeconomic structure, education), namely: Colombia, Chile, Mexico, Spain, the United States, and Canada. Second, this study examined the interpretive effects of applying the norms from the six target countries to the Colombian executive sample WAIS-IV data.

Determining how well a given individual or group is represented within a standardization sample, and in turn, how both relate to the broader population is a fundamental step in the test and norms selection process (Anastasi, 1981; Hamnbleton, et al., 2005). For this study, we specifically aimed to understand how well the education of our Colombian executive sample is represented at the WAIS-IV norms and population levels for the six target countries. Of the 305 Colombian executives, nearly all individuals completed post-secondary education (38.69% with bachelor’s degree/ISCED 4-6, and 60.98% with graduate education/ISCED 7-8). These education levels are well within the expected range for individuals hired into corporate executive roles in Colombia. Using the compiled data, the education levels of the WAIS-IV standardization samples was compared to current nation-level population statistics, then sample education was compared against both norm and population statistics. Education reporting across adaptations of the WAIS-IV varied widely. For the Colombian and Chilean adaptations, education was reported via a socioeconomic proxy variable. For the United States and Canadian WAIS-IV, education was reported using similar culturally significant milestones (e.g., high school, college/vocational, university) and slightly different milestones (primary, secondary, tertiary) were used in the Spanish WAIS-IV. The Mexican WAIS-IV did not report specific statistics on educational attainment. Considering the widely documented association between educational attainment and intelligence assessment performance (Flanagan & Harrison, 2012), along with the fact that these instruments are produced by the same publisher, it is surprising that education is not reported consistently across them. Additionally, none of the WAIS-IV technical information on education is reported using an international metric such as the ISCED. Without standardized reporting, it is not easy for psychologists to understand the cross-cultural meanings and implications within a given standardization process. Table 1.4 simplifies this comparison procedure for neuropsychologists looking to make comparisons between the WAIS-IV for any of the six target countries by converting everything into equivalent ISCED units (as best possible given currently reported technical information). From a cultural psychology perspective, development of future versions of the WAIS, as well as other psychometric instruments would benefit from rigorous detailed and consistent sociodemographics reporting, including categorization of education using the ISCED (UNESCO, 2012).

Another pitfall potentially facing cultural neuropsychologists is the assumption that the standardization sample of a well-known instrument like the WAIS-IV adequately represents its corresponding nation. This study demonstrates the danger in this assumption. After converting all data into ISCED units and comparing frequencies of post-secondary education at the sample, WAIS-IV, and population levels, several trends emerged. Post-secondary education is likely overrepresented in the Colombian and Chilean norms and thus, the education levels of our sample (albeit high) are likely well-captured within these norms; however, this is difficult to say with certainty because these norms use a socioeconomic proxy variable for education. Without education levels for the Mexican WAIS-IV it is nearly impossible to come to any conclusions about educational representation within the norms. In Spain, population levels of higher education occur at more than three times the rate in which they occur within the Spanish WAIS-IV. This means that the Spanish WAIS-IV norms might not be well-suited for individuals with advanced education, including the individuals in our sample. In the United States and Canada, population and WAIS-IV levels of education were most closely matched, despite WAIS-IV standardization sample alignment to census data from nearly a decade ago. While this suggests the education level of our sample may be well-captured within the United States and Canadian WAIS-IV norms, it also indicates that the quality of education being captured by these norms is notably different than that which is available to the 20% of the Colombian population that pursues higher education and that which is captured within the WAIS-IV norms for Colombia, Chile, Mexico, and Spain (Tables 1.2 and 1.3). Taking all of this information combined, the best a priori case could be made for using either the Colombian or the Chilean WAIS-IV norms with the present sample of Colombian executives as both have superior sociocultural and educational alignment with our sample as compared with the Mexican, Spanish, United States, and Canadian WAIS-IV. While the Colombian WAIS-IV would be the best a priori selection according to guidelines prioritizing use of local norms, the Chilean WAIS-IV would be the best a priori selection according to guidelines prioritizing most-local *and* best-psychometrically developed norms and has been routinely used in Colombia prior to the recent release of the Colombian WAIS-IV (Wechsler, 2016; and see Measures above).

For the second part of this study, these a priori hypotheses were tested by examining the interpretive effects of applying norms from the six target countries to the Colombian executive sample using ANOVA and percent agreement values (Colombian norms versus other norms) using three criteria: percent within 1/3 of a *SD*, percent within same descriptive classification level, and a more liberal combined criterion (percent within 1/3 *SD or* classification level). Overall, interpretive effects varied widely across norms applied. With the exception of the verbal subtest and VCI scores, highest mean scores were obtained using Colombian and Chilean norms (FSIQ, PRI, WMI, and PSI means in the high average to superior range), with incrementally lower scores obtained using norms from Mexico, Spain, the United States, and Canada with lowest mean scores falling in the average range. For the VCI, mean Colombian and Chilean scores were again similar, but higher means were obtained with norms from

Mexico and Spain (in the superior range) and lower with norms from the United States and Canada (in the high average range). Subtest scores followed these trends, to a narrower degree.

Despite some slight statistical differences between mean Colombian and Chilean FSIQ and index scores, there were no mean WMI or subtest differences and percent agreement across all scores using the three criteria was 100%. While mean Colombian and Chilean index scores for our sample tended to vary between one-half and one point, these results demonstrate that these differences have little-to-no clinical or interpretive meaning. This finding is surprising given that the Chilean norms were developed with a standardization sample nearly six times larger than that of the Colombian standardization sample. Although this study cannot speak to the presence or absence of underlying systematic differences between the Colombian and Chilean WAIS-IV norms, nor to findings that would be obtained when applying these norms to other samples, the results provide support for use of the Colombian norms in our sample because the scores do not have meaningful differences with those obtained with Chilean norms and offer better fidelity to local population representation.

While some could argue that in the absence of knowing the *true* intelligence scores for our sample, Colombian or Chilean norms may overestimate ability. However, comparing results obtained with Colombian (and Chilean) norms against results obtained with Mexican, Spanish, United States, and Canadian norms, all mean FSIQ, Index and subtest scores (except for cancellation) it is clear that these outside norms yield what should be considered significant underestimates given the known level of functioning across the sample. Percent agreement ranged vastly depending on criterion used, score examined, and selected norms. While the combined percent agreement criterion logically had the highest rates of agreement, the criterion using classification level typically, but not always, had the next highest rates of agreement. Further, combined percent agreement was consistently much higher on the subtest level over the index level. Specifically, highest rates of FSIQ/Index level score agreement were always found with the FSIQ and the VCI, followed by the PRI. Lowest rates of agreement were always found with the WMI and PSI. Similarly, the best agreement on the subtest level were always found with verbal and perceptual reasoning subtests and the worst agreement on subtests scores was found consistently with working memory and processing speed subtests. Further, the impacts of these inconsistent effects on score distributions when applying different norms are well-captured in Tables 1.5-1.6 and Figures 1.3-1.4. While it was more common for individuals scores to drop in clinical classification when applying norms from Mexico, Spain, the United States, and Canada, some scores changed by as much as ±3 clinical classification levels which is particularly substantial for a non-clinical, high ability sample. Overall, this demonstrates that our sample's level of acculturation to outside norms is low, even despite high education levels.

Some of the most surprising outcomes from this study are the patterns of findings across the index level. The VCI was the only index to have highest mean scores produced from norms other than those from Colombia and Chile: Mexican and Spanish norms produced mean VCI scores 4-7 points higher while United States and Canadian norms produced mean VCI scores 5-8 points lower than the mean Colombian VCI. Further, the VCI and verbal subtests had the highest percent agreement scores using the three established criteria. This finding is counterintuitive given the substantial literature linking education to enhanced verbal performance on the WAIS and the hypothesis that educational-cultural effects likely drive many intelligence test norm differences (Flanagan & Harrison, 2012; Lezak et al., 2012; Lynn et al., 2018). In fact, working memory and processing speed indices and subtests scores that neuropsychologists often think of as more "culture-free" had the worst percent agreement in this study. The exception to this was the cancellation subtest, which had the fewest score differences.

Although these findings cannot be used to make conclusive determinations about differences among the selected norms, they point to several key issues. First, these findings demonstrate that clinicians in this scenario who might be tempted to use Mexican, Spanish, United States, or Canadian norms for high performing, Colombian individuals with advanced education could run the risk of drastically under- (but occasionally over-) estimating WAIS-IV scores, and changing their within-score relation (i.e., patterns of strengths and weaknesses). For example, imagine a Colombian native moving to Spain and subsequently undergoing neuropsychological assessment. With Colombian norms, this person obtains an FSIQ of 114 falling into the high average range, with consistently high average index scores: VCI=113, PRI=116, WMI=111, and PSI=117. Using the relative differences from this study, when this same person is scored with Spanish norms they again obtain a high average FSIQ of 111, but their index scores would range from average to very superior, with a projected VCI of 120, PRI of 105, WMI of 101 and PSI of 106. Here, this study demonstrates the importance of neuropsychologists not only familiarizing themselves to an assessment instrument, but also to the broad and nuanced context of the assessment scenario (Cagigas & Manly, 2014; Hays, 2016; Judd, 2009). Second, notably different VCI score patterns suggests the verbal comprehension WAIS-IV construct may have some cultural nuances likely associated with education system differences and representation of advanced education in the Spanish and Mexican WAIS-IV standardization samples may be disproportion to national levels and to the other versions of the WAIS-IV examined in the study. Neuropsychologists must be aware that cultural adaptations may not adequately assess the constructs they are purported to assess, with variable structural and measurement equivalence (Bryne et al., 2009; Cagigas & Manly, 2014). Finally, the significantly low consistency of working memory and processing speed scores obtained from the six WAIS-IV norm sets suggests there may be substantial cultural effects associated with performance on these tests and/or differences in the psychometric treatment of these scores during the norms development process. These findings align with the cultural psychology and neuropsychology literature highlighting how cultural values such as competitive and quick thinking versus cooperative and deliberate behavior may affect test performance (Cagigas & Manly, 2014). For all of these issues, greater access to technical information for cultural-adaptations of the WAIS-IV and increased studies examining their psychometric properties in standardization, non-clinical, and clinical samples would help clarifying factors contributing to cross-test norm differences.

Numerous strengths make this study a useful contribution to the cultural neuropsychology literature. It is the first study to make systematic comparisons of WAIS-IV norms from multiple Spanish-speaking countries and it supports previous research demonstrating systematic score differences when applying norms from the United States and Canada (Harrison et al., 2014; Iverson et al., 2006). It also integrates methods to culturally contextualize data which provide decision-making considerations and resources for cultural neuropsychologists, particularly those working with native Spanish speakers. This study highlights the fact that cross-cultural test standardization procedures are not always equivalent, even when overseen by the same multination test company. It also emphasizes the importance of thorough technical reporting for psychometric instruments and calls for test developers to incorporate metrics that facilitate cross-cultural work, such as the ISCED. Additionally, this study helps raise further awareness to American-Eurocentric assessment bias, such cultural advantage/disadvantage assumptions for individuals from developing nations, and highlights application of culturally responsive assessment practices (Hays, 2016).

A number of limitations and areas for improvement are also apparent in this research. First, the results of this study should not be used as the basis of clinical decision-making. The study is limited by a sample of convivence, and better understanding of inherent norm differences between the selected versions of the WAIS-IV could only be obtained through direct comparison of the original normative data as well as examination of the effects when applying norms to more diverse clinical and non-clinical samples, ranging more widely in socioeconomic background and ability. While this study outlines some cultural assessment resources and decision-making frameworks for this particular assessment scenario, it is far from providing the more comprehensive set of resources needed within the field of cultural neuropsychology to adequately respond to increasing demands. In acknowledgment of these limitations, however, this study demonstrates some of the first steps that can be taken in responses to the call for clinical neuropsychology "to reinvent itself in face of global increases in diversity, and an increased focus on the development of new, theoretically and clinically viable approaches to measurement […] applicable locally as well as globally" (Suchy, 2016, pp. 973).

Chapter 2. Examining Bifactor and Hierarchical Intelligence Factor Structures in the Chilean adaptation of the WAIS-IV*

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*Manuscript to be submitted to *Intelligence.*

All work in this chapter was conceived of and carried out by me, with the exception of the critical feedback incorporated into the execution of some analyses and the writing of this manuscript by my other committee members.

Abstract

Objective: Accumulating evidence indicates the original factor structure published in the Wechsler Intelligence Scales (Wechsler, 2008b, 2008c) may not best describe the data captured by these tests. Instead some evidence supports a five-factor Cattell-Horn-Carroll (CHC) model (Benson et al., 2018; Weiss et al., 2013b) over a four-factor Wechsler model, and a bifactor model over a higher-order model (Gignac, 2016). Considering most extant research focuses on North American samples, our study objectives were to examine the psychometric properties and determine the best model fit of the Chilean Wechsler Adult Intelligence Scale-Fourth Edition (WAIS-IV; Wechsler, 2013; Rosas et al., 2013). **Participants and method:** Confirmatory factor analysis was used to evaluate the factor structure of the Chilean-WAIS-IV normative sample (ages 16-69, N=672). Four-factor and five-factor models were examined in oblique, higher order, and bifactor variants and compared using fit indices. The Schmid-Leiman (1957) procedure was compare higher-order and bifactor loadings. **Results:** Cross-loading the arithmetic subtest on a verbal factor resulted in negative loadings. As hypothesized, the five-factor CHC models fit better than the four-factor Wechsler models (average ΔCFI=+0.014). Also, bifactor models fit better than traditional higher-order models (four-factor ΔCFI=+0.016 and five-factor ΔCFI=+0.012). Overall, a bifactor CHC model (based on Weiss et al., 2013b) best fit the data (CFI=0.996, RMSEA=0.025); but the Schmid-Leiman transformation demonstrated high similarity between the bifactor and higher-order model variants. **Conclusions:** This research contributes to the much-needed cross-cultural study of alternative WAIS-IV factor models and our results are consistent with the growing literature supporting a five-factor CHC model in WAIS-IV data. While results have implications for the clinical interpretation of the Chilean WAIS-IV (e.g., conceptualizing full-scale intelligence quotient as a breadth factor rather than a superordinate factor of index-level abilities), further studies examining the clinical utility of WAIS-IV bifactor and CHC models are needed.

Introduction

The Wechsler intelligence scales for adults (WAIS-IV; Wechsler, 2008b, 2008c) and children (WISC-V, Wechsler, 2014b; WPPSI-IV, Wechsler, 2012c;) are the among the most widely used assessment instruments in the world (Rabin, Paolillo, Barr, 2016). Because of this, substantial research has scrutinized the theoretical underpinnings and psychometric quality of the Wechsler scales, ultimately leading to significant changes and improvements through their revisions (Benisz, Dumont, & Willis, 2015). Perhaps the greatest change has been moving from a largely atheoretical orientation to increasing alignment with the Cattell-Horn-Carroll (CHC) model of cognitive abilities (Flanagan, McGrew, & Ortiz, 2000; Wechsler, 2008b, 2008c; Wechsler, 2014b).

The CHC model is a theoretically-driven, and psychometrically-based integration of research on intelligence and cognitive ability conducted since the beginning of the 20th century (Schneider & McGrew, 2012). Evident in its name, it combines two of the most prominent psychometric cognitive ability theories, Horn-Cattell Gf-Gc theory (Horn & Cattell, 1966) and Carroll's three-stratum theory (Carroll, 1993), which both grew out of Spearman's influential (and subsequently well-replicated) research demonstrating the tendency for all mental ability tests to be positively correlated (the positive manifold; Spearman, 1904; Jensen, 1998). Essentially, CHC theory describes cognitive abilities in three levels, with numerous narrow abilities (striatum one) that can be clustered into general abilities (striatum two), which then give rise to general intelligence (*g*) at the apex of the model (stratum three). While evidence remains incomplete as to the precise number of narrow and broad abilities, there appear to be at least 10 and perhaps up to 20 (striatum two) clusters of narrow abilities, including: fluid intelligence (Gf), crystallized intelligence (Gc), short-term memory (Gsm), visual processing (Gv), and auditory processing (Ga), long-term storage and retrieval (Glr), processing speed (Gs), quantitative knowledge (Gq), reading and writing ability (Grw), and reaction time (Gt; Schneider & McGrew, 2018; Woodcock, Maricle, Miller, & McGill, 2018). While CHC theory is far from being a comprehensive or complete cognitive model and is not without flaws or criticism, it has provided an adaptive framework, capable of being applied to a wide range of contemporary psychometric research (Schneider & McGrew, 2018). To date, the CHC model is the most well-supported and utilized model of cognitive abilities (Jewsbury, Bowden, & Duff, 2016; Schneider & McGrew, 2018; Woodcock et al., 2018).

In its current iteration, the WAIS-IV is described as a four-factor, higher-order model (Wechsler, 2008c). The 10 core subtests and five additional supplementary subtests (analogous to striatum one abilities) give rise to four (striatum two) factors representing verbal abilities (Verbal Comprehension Index; VCI), perceptual reasoning abilities (Perceptual Reasoning Index; PRI), working memory abilities (Working Memory Index; WMI), and speed of cognitive processing (Processing Speed Index; PSI). Combined, these four factors are indicators of an overall intellectual ability (striatum three) factor (Full-Scale Intelligence Quotient; FSIQ). In further relating the CHC model to the traditional Wechsler factor structure, it has been shown that the VCI is akin to crystallized intelligence (Gc), WMI akin to short-term memory (Gsm), and PSI akin to processing speed (Gs), while PRI appears to capture a combination of fluid intelligence (Gf) and visual processing (Gv; Keith & Reynold, 2018). Thus, when describing the WAIS-IV in terms of the CHC framework, the Wechsler four-factor model is adjusted into a five-factor CHC model, by having a slightly different arrangement of factor loadings, which then give rise to a broader general intelligence factor (*g*).

Overall, accumulating research has provided psychometric support for many iterations of five-factor, CHC-derived models (Gc, Gv, Gf, Gsm, and Gs) in the Wechsler scales (Benson, Hulac, & Kranzler, 2010; Canivez & Watkins, 2010a, 2010b; Gignac & Watkins, 2013; Lecerf, Golay, Reverte, Senn, Favez, & Rosseir, 2012; Lecerf, Golay, & Reverte, 2012; Jewsbury, et al., 2016; Keith & Reynolds, 2010; Niileksela, Reynolds, & Kaufman, 2013; Ward, Bergman, & Hebert, 2012; Weiss, Keith, Zhu, & Chen, 2013b). While research has demonstrated acceptable fit of both four-factor (VCI, PRI, WMI, and PSI) and five-factor (Gc, Gv, Gf, Gsm, and Gs) models in the WAIS-IV, five-factor models have generally been favored for displaying better psychometrics and alignment with the well-supported CHC model (Alfonso, Flanagan, & Radwan, 2005; Benson et al., 2010; van Aken et al., 2017; Weiss et al., 2013b).

In considering the broader world of intelligence tests, a number of factor-analytic review and meta-analytic papers (including data from the Wechsler scales) have concluded that most widely-used intellectual and cognitive tests theoretically and psychometrically align with CHC theory, either explicitly, like the CHC-driven Woodcock-Johnson Tests of Cognitive Abilities (Schrank, Mather, & McGrew, 2014), or implicitly, as it is the case for the Wechsler scales (Benson, Beaujean, McGill, & Dombrowski, 2018; Grégoire, 2013; Jewsbury, Bowden, & Duff, 2016; Keith & Reynolds, 2010). Researchers, however, have disagreed on the specific way the CHC model represents, and should be fit to, the data derived from intelligence tests (as evidenced the numerous variations how the CHC model has been applied to intelligence data; c.f. Flanagan & Harrison, 2018; Grégoire, 2013;). Thus, this disagreement has added significant complexity to the CHC picture.

In general, the current limitations within the CHC psychometric literature can be characterized by two overarching themes: model specification (configuration) and broader model structure. First, since the Wechsler scales are not explicitly developed based on the CHC model, exploratory or confirmatory factor analysis is used to determine how individual subtests may fit into a CHC model configuration. In practice, this results in the foundational four-factor model of the WAIS-IV (with two or three subtests on each factor/index) being reconfigured with several cross-loaded subtests to result in five factors (Gc, Gv, Gf, Gm, and Gs) aligning with the CHC model (see Figures 2.1 and 2.2, Panels 1 and 2). Four and five-factor model fit statistics are then typically compared in some fashion to determine the model that best describes the intelligence data. With cross-loadings, however, comes more room for complexity of analysis and interpretation, and studies have ranged from testing a single model to testing over 20 configurations (or modifications) of each four and five-factor models (see Table 2.1 for a summary of models tested in factor analysis studies of WAIS-IV scales). The inconsistency of model configurations tested across studies actually makes it remarkably difficult to make direct comparisons and draw conclusions from the broader research.

The second main difficulty within the literature has to do with the way the broad and specific factors are structured in relation to one another. As originally published (Wechsler, 2008c), a higher-order factor structure was used to conceptualize and evaluate the Wechsler scales, with each subtest as an indicator of a factor (index), and each factor an indicator of a higher-order mental ability factor (e.g., FSIQ/*g*; see Figure 2.1, Panels 1 and 2). Conveyed within the higher-order model is the premise that each subtest entirely contributes to its parent factor, and those factors alone give rise to the higher-order construct of general mental ability (FSIQ/*g*). Subsequent work has further evaluated higher order models in the Wechsler intelligence scales, and many researchers present strong arguments for the theoretical rationale as to why a higher-order model is preferable to alternate models (e.g., Keith & Reynolds, 2018; Weiss, Keith, Zhu, & Chen, 2013a; 2013b). Other researchers disagree with this notion, asserting that information from individual subtests may best be described as directly contributing to the general factor (FSIQ/g) first, and then secondarily (through remaining unaccounted variance) to striatum two (index level) factors, often referred to as a bifactor model (see Figure 2.1, Panel 3). Much of this thinking has been driven by revisiting the underpinnings of Spearman and Cattell's work (Benson, Beaujean, McGill, & Drombrowski, 2018; Kan, Klevit, Dolan, & van der Maas, 2011; Warne & Burningham, 2019) and many researchers have provided support for the bifactor model in WAIS and other intelligence data (e.g., Cucina & Byle, 2017; Frisby & Beaujean, 2015; Gignac, 2008; Gignac & Watkins, 2013).

The arguments for and against the application of higher-order and bifactor models have been increasingly documented in the literature. While accumulating research has shown that bifactor models tend to have slightly better fit indices than their higher-order counterparts, several papers demonstrate the overfit tendency of the bifactor model and argue that the models are not-directly comparable (without statistical corrections) due to differences in model parameters, essentially resulting in comparing apples with oranges (Gignac, 2008; Gignac, 2016; Keith & Reynolds, 2018; Mansof, 2017; Reise, Schenies, Widaman, & Haviland, 2013). While consensus has yet to be reached on the theoretical validity of a higher-order versus bifactor model (largely due to lack of consensus for a unified definition of intelligence), few papers tend to take an agnostic approach and test either higher-order models or bifactor models, but not both (Table 2.1).

While the two main issues of model configuration and model structure are well-discussed in the literature, there is a third often overlooked issue relating to the lack of data diversity within this body of research. Despite a prolific amount of research on CHC theory in intelligence assessment, proportionately little work has been done to validate the CHC model cross-culturally in current intelligence batteries (Jewsbury et al., 2016; Schneider & Flanagan, 2015). In fact, to our knowledge, most Wechsler factor structure papers draw from North American and European samples and many papers are analytic variants using the same (often standardization sample) data (Table 2.1). This is surprising because the WAIS-IV (Wechsler, 2008b) alone currently has at least 26 international cultural and language adaptations (Pearson Clinical, 2019). Additionally, recent work has shown inconsistent patterns of WAIS-IV subtest and index standardized scores across different national standardization samples, which may point to underlying differences in psychometric properties (Duggan, Awakon, Loaiza, & Garcia-Barrera, 2018). Given the incredible influence of CHC theory in contemporary intelligence assessment, as well as the international popularity of the Wechsler scales, further cross-cultural work in this area is essential.

Here, this study extends prior research to South America by examining the factor structure of the Chilean WAIS-IV standardization data (Wechsler, 2013). Specifically, confirmatory factor analysis (CFA) was used to consistently examine model configuration (the Wechsler index-based four-factor model and the CHC-based five factor model) and model structure (higher-order and bifactor models).

We anticipated that all models would display adequate fit and good psychometric properties, including commonly used cross-loadings and other model variants, as described in the extant literature. We hypothesized that five-factor models would demonstrate more robust psychometric properties than four-factor models. We also anticipated bifactor models to demonstrate stronger fit statistics than higher-order models, but that bifactor and higher-order factor loadings would be similar after applying the necessary transformation to make them directly comparable.

Within a sociocultural framework, this study more broadly evaluates the cross-cultural construct validity of the WAIS-IV. While adaptations of the WAIS-IV are based on the premise of universalism, or "culture-free" intelligence, research has shown this concept to be misguided and incorrect, with systematic group differences demonstrated in a range of neuropsychological testing, particularly in nonverbal measures (Duggan et al., 2018; Gasquoine, 1999; Rosselli & Ardila, 2003; Olson & Jacobson, 2014). Given the unlikely universalism of entire WAIS-IV, we hypothesized that differences in subtest and index factor loadings in the Chilean WAIS-IV factor models would exhibit relative differences from those seen in United States models, despite expecting good fit of the overall Wechsler and CHC models.

Methods

Measures

The Chilean version of the WAIS-IV (Wechsler, 2013; Rosas et al., 2014) is an adaptation of the Spanish WAIS-IV (Wechsler, 2012a), which was the first Spanish-language test adapted from the original United States WAIS-IV (Wechsler, 2008b, 2008c). The Chilean WAIS-IV includes the same subtests, items, and score structure as the Spanish and United States WAIS-IV, with only minor cultural adaptations to item content/scoring. Consequently, it has 10 core subtests (Similarities [SI], Vocabulary [VC], Information [IN], Block Design [BD], Matrix Reasoning [MR], Visual Puzzles [VP], Digit Span [DS], Arithmetic [AR], Symbol Search [SR], and Coding [CD]) and five supplemental subtests (Comprehension [CO], Figure Weights [FW], Picture Completion [PC], Letter-Number Sequencing [LN], and Cancellation

[CA]), which yield four index scores (Verbal Comprehension Index [VCI], Perceptual Reasoning Index [PRI], Working Memory Index [WMI], and Processing Speed Index [PSI]) and a Full-Scale Intelligence Quotient (FSIQ). According to the Chilean WAIS-IV technical data, internal consistency for the test as whole (FSIQ) is 0.941, with mean index alpha coefficients of 0.951 for VCI, 0.874 for PRI, 0.912 for WMI, and 0.854 for PSI, and subtest reliabilities ranging from 0.733 to 0.925. These reliabilities are comparable to those reported in the United States WAIS-IV manual (mean reliability for United States FSIQ=0.98, VCI=0.96, PRI=0.95, WMI=0.94, PSI=0.90, and subtests ranging from 0.78 to 0.94). Additional technical information about the Chilean WAIS-IV is provided in the administration manual (Wechsler, 2013) and the accompanying technical paper (Rosas et al., 2014).

Participants

This study used the original Chilean WAIS-IV standardization sample data, which comprises 887 Chilean, Spanish-speaking individuals ages 16:00 to 90:11 years, representative of the general Chilean population (Wechsler, 2013; Rosas et al., 2014). Individuals aged 70 years and older were excluded from this study because they were administered only 12 of the 15 WAIS-IV subtests (FW, LN, and CA omitted). Thus, the final sample for this study was 672 individuals who completed all 15 WAIS-IV subtests (M_{age}=36.93, SD_{age}=17.12, 50.45% women). Demographic and descriptive statistics for this sample are provided in Supplementary Tables 2.1 and 2.2. Ethnicity is not reported in the Chilean WAIS-IV. Data was used with permission from the standardization team and approved by the Human Research Ethics Board at the University of Victoria (Protocol Number 18-129).

Procedure

All descriptive statistics were calculated using SPSS Statistics Version 25 (IBM, 2017) and confirmatory factor analysis was conducted in Mplus Version 8 (Muthén & Muthén, 1998-2017). Standardized subtest scores were used for analysis. Data screening included examination of missing data patterns, evaluation for univariate normal distribution for each variable (skewness and kurtosis), and evaluation of multivariate normality (Mahalanobis' distance). In Mplus, the default for missing data is the maximum likelihood method of estimation (Muthén & Muthén, 1998-2017). In the event of outliers, data would be excluded. A series of four- and five-factor models were determined a priori, based on the most consistently tested and empirically supported WAIS-IV factor models (and their cross-loading and/or correlated residuals). The correlation matrix (standardization sample ages 16-69 years, N=672) is presented in Supplemental Table 2.3.

All models were tested in oblique, higher-order, and bifactor variants as depicted in Figures 2.1 and 2 and specified in Table 2.2. Four-factor models were based on the original Wechsler model and its final cross-loading variant (four-factor Models A-E; see Table 2.2 and Figure 2.1; Wechsler, 2008c; Rosas et al., 2013). Five-factor models were based on the two most commonly referenced five-factor model variants from the literature. First, we evaluated a five-factor, CHC-model based on the configuration reported by Benson et al. (2010) (five-factor A) and its cross-loading variant (five-factor B; Ward et al., 2012). Second, we evaluated the five-factor model originally specified by Weiss et al. (2013b) (five-factor C) and its cross-loading variant (five-factor D; Benson et al., 2010; Ward et al., 2012; Weiss et al., 2013b). This model is unique in that it has an intermediate first order factor, called Quantitative Reasoning (RQ), which is indicated by FW and AR subtests, then loaded on Gsm. Modification indices were examined post-hoc to inform interpretation and discussion but were not implemented into any models.

Models were evaluated using chi-square (χ^2) test, comparative fit index (CFI), Tucker-Lewis index (TLI), Akaike information criterion (AIC), Bayesian information criterion (BIC), adjusted BIC (aBIC), root mean square error of approximation (RMSEA), and standardized root mean square residual (SRMR). The established conservative cutoff criteria for fit indexes (i.e., CFI/TLI = 0.90, RMSEA < 0.08) and stringent cutoff criteria (i.e., CFI/TLI = 0.95, RMSEA < 0.05, incremental χ^2 and AIC/BIC/aBIC closer to zero the better) were used for model comparison (Hu & Bentler, 1999; Jackson, Gillaspy, & Purc-Stephenson, 2009; Marsh, Balla, & McDonald, 1988; Brone & Cudek, 1993 as cited in Schermelleh-Engel, Moosbrugger, & Müller, 2003; Schreiber, Nora, Stage, Barlow, & King, 2006). The Schmid-Leiman procedure was used to calculate the contribution of lower- and higher-order factors to the prediction of observed measures (Schmid & Leiman, 1957) and make them comparable to bifactor loadings (Brown, 2015; Gignac, 2016).

Model-based reliabilities were estimated using omega (ω), an estimate that represents the of true-score variance to total variance of indicators of a given factor (McDonald, 1999; Reise, 2012). Omega-hierarchical (ω_H) was used to estimate model-based reliability for FSIQ/g with the variability of first order factors removed. Omega-hierarchical subscale (ω_{HS}) was used to estimate group factor reliability with all other group and general factors removed (Brunner, Nagy, & Wilhelm, 2012; Rodriquez, Reis, & Haviland, 2016). While there are no empirically based and clinically applicable guidelines for acceptable levels of omega coefficients, values of at least 0.50 (adequate) to 0.75 (preferred) are suggested sufficient for interpretation of construct-based reliability for group or hierarchical factor interpretation (Reise, 2012; Reise, Bonifay, & Haviland, 2013; Reise, Scheines, Widaman, & Haviland, 2013).

Results

Demographic and descriptive statistics for this sample are provided in Supplementary Tables 2.1 and 2.2. Data screening showed that the final Chilean WAIS-IV standardization sample had no missing data, no outliers, and an approximate univariate normal distribution for each variable (skewness and kurtosis within normal limits). Fit statistics for all models are presented in Table 2.3. All models converged normally, except two models yielded non-positive definite covariance matrices (four-factor bifactor Model B and four-factor bifactor Model C). All oblique models with an AR cross-loading on VCI/Gc yielded a negative factor loading for that subtest (standardized loading ranging from -0.166 to -0.313 for Model 4 = -0.313, Model 5 = -0.273, Model 7 = -0.166, and Model 9 = -0.261). Consequently, all higher-order and bifactor models with this variant were subsequently excluded and fit statistics are not reported. Overall, model fit improved with model complexity, as shown by progressively lower (less inflated) χ^2 values, improved (lower) RMSEA and SRMR values, and larger CFI, TLI, AIC, BIC, and aBIC values. Though oblique models demonstrated suboptimal fit-indices, higher-order and bifactor variants demonstrated adequate to excellent model fit, consistent with the Wechsler intelligence scale literature. Factor loadings for all best Wechsler and CHC models are summarized in Supplemental Table 2.4.

Four-factor (Wechsler) models

Four-factor Model C was the best fitting four-factor model for both higher-order and bifactor variants (Models 12 and 21, respectively, Table 2.3). The higher-order variant demonstrated acceptable fit (χ^2 = 219.72, *df* = 84, RMSEA = 0.049, SRMR = 0.290, CFI = 0.978, TLI = 0.972, AIC = 45301.89, BIC = 45531.91, aBIC = 45369.98). For this model, WMI and PRI were the most robust indicators of FSIQ (λ = .936), followed by VCI (λ = .797), and PSI (λ = .763, all p < 0.0005). All subtests were moderate to strong indicators (mean λ = .722, highest λ = .872 for VC on VCI, lowest λ = .359 for FW on PRI, all p < 0.0005). The bifactor variant demonstrated excellent fit but ultimately yield a non-positive definite covariance matrix (χ^2 = 105.45, *df* = 67, RMSEA =. 0.029, SRMR = 0.018, CFI = 0.994, TLI = 0.990, AIC = 45221.61, BIC = 45528.61, aBIC = 45312.40).

Five-factor (CHC) models

Five-factor Model C was the best fitting five-factor model for both higher-order and bifactor variants (Models 17 and 26, respectively, Table 2.3). The higher-order variant demonstrated acceptable fit (χ^2 = 181.89, *df* = 82, RMSEA = 0.043, SRMR = 0.027, CFI = 0.984, TLI = 0.979, AIC = 45268.05, BIC = 45507.10, aBIC = 45338.82, Figure 2.3). For this model, Gf was the most robust indicator of *g* ($\lambda = 1.00$), followed by Gv (λ = .875) and Gc (λ = .875), Gsm (λ = .830), then Gs (λ = .757; all p < 0.0005). All subtests were strong indicators with the exception of FW on Gv (λ = .144, p = 0.058), MR on Gv (λ = .193, p = 0.005), and AR on Gsm (λ = .261, p < 0.0005).

The bifactor variant demonstrated excellent fit (χ^2 = 87.90, df = 62, RMSEA = 0.025, SRMR = 0.016, CFI = 0.996, TLI = 0.993, AIC = 45214.06, BIC = 45543.31, aBIC = 45311.53, Figure 2.4). All subtests were moderate to strong indicators of *g* (mean $\lambda = .650$, all $p < 0.0005$; highest $\lambda = .868$ for VC, lowest $\lambda = 0.379$ for CA). After accounting for their contributions to *g*, indicators were observed to have a range of contributions to broad factors from no significant contributions (i.e., $p > 0.05$ for all indicators of Gc, MR and FW on Gv, FW on RQ, MR on Gf, and AR on Gsm) to moderate contributions (e.g., SS on Gs, $\lambda = .697$, DS on Gsm, $\lambda = .630$, VP on Gv, $\lambda = .557$, BD on Gv, $\lambda = .554$, and CD on Gs, $\lambda = .531$; all $p < 0.0005$).

Combined results

As hypothesized, the five-factor (CHC) models fit better than the four-factor Wechsler models (average ΔCFI=+0.014). Also, bifactor models fit better than traditional higher-order models (four-factor ΔCFI=+0.016 and five-factor ΔCFI=+0.012). Overall, five-factor Model C was the best fitting higher-order model (Table 2.3, Model 17; Figure 2.3) and bifactor model (Table 2.3, Model 26; Figure 2.4), with the latter being the ultimate best-fitting model. The omega reliability estimates for *g* were robust (ω_H = 0.92) and insufficient for all specific factors, except Gs: ω_{Hs} (Gc) = 0.0001, ω_{Hs} (Gv) = 0.20, ω_{Hs} (Gf) = 0.24, ω_{Hs} (Gsm) = 0.32, ω_{Hs} (Gs) = 0.56.

Given differences in parameter estimates in the higher-order and bifactor models making direct comparison difficult, a Schmid-Leiman transformation of the best higher order model (five-factor Model C; Table 2.3, Model 17) was used to better examine it in relation to its bifactor variant (Table 2.3, Model 26). The Schmid-Leiman transformation estimates of the higher-order model (Table 2.4) show the effects of *g* across the subtests were the strongest (mean effect = 0.57), with lower mean effects for the specific factors (Gc = 0.40, Gv = .29, Gf = 0.00, Gsm = 0.30, Gs = 0.35). These estimates were generally slightly lower, but similar to, the mean effects for the bifactor model (*g* = 0.65, Gc = 0.02, Gv = 0.32, Gf = 0.57, Gsm = 0.44, Gs = 0.56).

Modification indices for each model were examined post-hoc to evaluate if any important model variants were erroneously excluded from these analyses. None of the modification indices were found to substantially differ from, or theoretically add to, any of the 27 models tested.

Comparison to United States WAIS-IV data

For the best-fitting higher-order model (five-factor Model C [Model 17] Figure 2.3, Table 2.3), index factor loadings ranged from 1.0 (Gf) to 0.757 (Gs), and subtest loadings ranged from 0.871 (VC) to 0.144 (FW on RQ). The highest five loadings were VC (0.871), IN (0.832), CO (0.808), and SI and BD (both 0.802). Comparing this model with the same model fit to data from the United States WAIS-IV standardization sample (Weiss et al., 2013), nearly all factor loadings have similar values and loadings patterns. More specifically, index loadings in the United States data ranged from 0.99 (Gf) to 0.67 (Gs), and subtest loadings ranged from 0.89 (VC) to 0.23 (AR), with the highest five loadings including VC (0.89), 0.85 (DS), 0.83 (CO), 0.82 (SI), and 0.81 (BD). The mean difference between the Chilean and the United States index loadings was 0.05 (range = 0.01 [Gf] to .09 [Gs]), and the mean difference between subtest loadings was 0.08 (range = 0.01 to 0.47). The only subtest loadings to have a mean difference greater than 0.10 were FW on Gv (mean difference = -0.47), LN on Gsm (-0.23), FW on RQ (+0.16), PC on Gv (+0.15), and MR on Gf (+0.11).

For the best-fitting bifactor model (five-factor Model C Figures 2.4; Table 2.3 Model 21), direct comparison to the identical model in the United States WAIS-IV or other data was not available, since to our knowledge, findings regarding this model variant has not yet been reported in the literature (see table 2.1). Overall, subtest factor loadings on g ranged from 0.77 (AR) to 0.41 (CA), with the five highest loadings including AR (0.77), FW (0.74), and SI/VC/MR (all 0.71). These can roughly be compared to the best reported model: the five-factor, bifactor model fit to United States WAIS-IV standardization data (Gignac, 2014), which breaks DS into its three components (forwards, backwards, and sequencing). In this model, subtest factor loadings ranged from 0.74 (MR and SI) to 0.42 (DS forward), with the five highest loadings including MR and SI (0.74), 0.71 (AR), 0.69 (VC and BD).

Discussion

Rigorous examination of factor structure is critical to providing psychometric evidence for the use of intelligence tests, as well as to aid with understanding consistencies and areas for improvement in contemporary intelligence models and measures. In this study, we evaluated the factor structure of the Chilean WAIS-IV in a manner specifically designed to contribute to three areas of ongoing Wechsler intelligence scale research: 1) consistent evaluation of model configuration (four- versus five-factor models), 2) consistent evaluation of factor structure (higher-order versus bifactor models), and 3) evaluation of WAIS-IV data in an underexamined population. Specifically, this study used review of extant research to establish a systematic, a priori set of models to comprehensively evaluate the factor structure of the Chilean WAIS-IV.

Oblique versions of all models were tested first before adding model complexity with higher-order and bifactor structures. This step was also important given that oblique models are part of reporting in the Wechsler manuals (e.g., fit statistics for the final model are reported for both oblique and higher-order variants; Wechsler, 2008c) and they relate substantially to how the Wechsler scales are often used in clinical practice (analysis of performance on index scores and even subtest scores; Staffaroni et al., 2018). While all oblique models converged normally and generally showed improved fit indices with increasing model complexity, all arithmetic cross-loadings onto a verbal factor (VCI/Gc) resulted in a negative factor loading. This finding was not fully anticipated since the AR cross-loading is not only part of the final United States WAIS-IV reported model (Wechsler, 2008c, AR cross-loading = 0.08) but also reported in several other studies in North American and European studies (e.g., Weiss et al., 2013b, AR cross-loading = 0.22; van Aken et al., 2017, AR cross-loading = 0.32). At least one other study, however, showed a negative cross-loading of AR on Gc in a clinical population (Staffaroni et al.,

2018) and it is possible other studies encountered, but did not report, a similar finding. While this may be a sample-based result (i.e., AR contributes to a verbal factor in some clinical or cultural samples but not in others), it more likely suggests that an alternate factor structure may better describe the data (e.g., an AR cross-loading on Gc is may be erroneous and inconsistent finding, or CHC model may better describe the data than a Wechsler model; Staffaroni et al., 2018).

While most four- and five-factor models in our study demonstrated adequate convergence and fit, the statistics for the five-factor models were notably stronger. Our findings support the alternative CHC factor structure in the Chilean WAIS-IV and are consistent with other research applying the CHC model in different WAIS-IV samples (Table 2.1). The best fit indices were observed with variants of five-factor Model C (Figures 2.3 and 2.4; Table 2.3 Models 17 and 21), which feature the RQ factor based on the model described by Weiss et al. (2013b) and others (Pezzuti et al., 2018, Staffaroni et al., 2018, van Aken et al., 2017). A simpler five-factor CHC model (Model A; Table 2.3 Models 15 and 19), based on the one outlined by Benson et al., (2010), however, also demonstrated excellent fit statistics that were only slightly behind Model C's indices. While five-factor Model C was presented as the best fitting model in the results (based solely on the numbers alone), our findings ultimately provide no clear evidence in favor of one five-factor model over the other. Similarly, the same argument could be applied to selecting a four- or five-factor model based on our findings, the best of which all demonstrated adequate fit statistics. Ultimately clinical selection of models should be based both on fit *and* theoretical rationale; while an argument could be made for parsimony (less factors being more favorable due to a high risk of over-factorization; Frazer & Youngstrom, 2007), CHC theory has substantially prevailed and numerous arguments in favor of CHC models have been well presented throughout the literature (e.g., Benson et al., 2010; Staffaroni et al., 2018; Weiss et al., 2013b).

Given the prevalence of well-supported arguments for the use of both four- and five-factor models in the WAIS-IV, some guidance on model utilization may come from examination of research from other CHC aligned intelligence tests, including the Wechsler Intelligence Scales for Children and the Woodcock-Johnson Tests of Cognitive Abilities. The recent release of the WISC-V (Wechsler, 2014b) incorporated significant changes, which continue the Wechsler intelligence scales development trend of further alignment with the CHC model. Specifically, this edition moved from the well-established four-factor model using a 15-subtest battery (i.e., VCI, PRI, WMI, and PSI as seen in the WISC-IV and the WAIS-IV) to a 16-subtest battery with a five-factor structure (VCI, WMI, PSI, plus visual spatial index [VSI, akin to Gv], and fluid reasoning index [FRI, akin to Gf]). While much WISC-IV research provided support for this shift, demonstrating better fit of a five-factor model over a four-factor model (e.g., Golay, Reverte, Rossier, Favez, & Lecerf, 2012; Keith, Fine, Taub, Reynolds, & Kranzler, 2006; Reverte, Golay, Favez, Rossier, & Lecerf, 2015; Weiss Keith, Zhu, & Chen, 2013c), accumulating research evaluating the WISC-V has somewhat reversed this momentum, indicating the WISC-V may over factor and now providing support for the four-factor model over the five-factor model (e.g., Dombrowski, Canivez, & Watkins, 2018; Dombrowski, Canivez, Watkins, & Beaujean, 2015; Canivez, Dombrowski, & Watkins, 2018; Fenollar-Cortés & Watkins, 2018; Lecerf & Canivez, 2017). In a similar vein, the current edition of the Woodcock-Johnson Tests of Cognitive Abilities (WJ-IV; Schrank, McGrew, & Mather, 2014), a test specifically developed from CHC theory, with 18 subtests yielding eight factors, has also been shown to potentially over factor its data (Dombrowski, McGill, & Canivez, 2017; 2018a; 2018b). While alignment with contemporary intelligence theory is a critical basis of intelligence assessment, these research findings alert us to the potential of over fitting data using indicators that may be too few in number (estimating factors with two indicators; March, Hau, Balla, & Grayson, 1998) or impure (subtests being used to indicate multiple factors; Murray & Johnson, 2013, cf. Karr, Areshenkoff, Rast, Hofer, Iverson, & Garcia-Barrera, 2018 in the executive functioning literature). As a revision of the WAIS-IV is expected to be released soon and is anticipated to incorporate similar changes as the WISC-V to further align it with the CHC model, more research will be needed to examine the theoretical, psychometric, and clinical underpinnings of the Wechsler scales.

The issues of potential under identification and over-factorization also more broadly relate to the debate surrounding the use of higher-order versus bifactor model structures in intelligence data (Keith & Reynolds, 2018). In this study, bifactor variants of nearly all models appeared to fit better than their higher-order counter parts (with the exception of the four-factor bifactor models with resulted in a non-positive definite covariance matrix); however, given the differences in model specification, bifactor models are inherently expected to fit better and additional considerations must be taken to examine the presence of any meaningful differences (Gignac, 2016; Mansof & Reise, 2017; Murray, 2013; Reise, 2013; Rodriguez, 2016). The Schmid-Leiman (1957) was used to calculate the factor contributions within the higher-order model to the subtest indicators and make them comparable to the loadings of the bifactor model (Brown, 2015; Gignac, 2016; Schmid & Leiman, 1957). While the statistical utility of this procedure has been debated (Mansof & Reis, 2017), and considerably more complex methods could be used to make a more exact mathematical comparison (e.g., Yang, Caemmere, & Reynolds, 2016), the approach was deemed acceptable for the purposes of this paper. Our results demonstrated high similarity between the model variants, indicating no clear evidence in favor of the either bifactor or high-order models.

Given our results in the context of increasingly popular bifactor models that lack clarity on their theoretical and clinical distinctions from higher-order models, several issues warrant further discussion and investigation. First, to what extent are factor structures simply driven by model complexity? As demonstrated in our review of key papers examining WAIS-IV factor structure (Table 2.1), models tested across papers vary widely, particularly in terms of factor structure, model configuration, and modification indices. This makes it unclear if certain models (e.g., four-factor versus five-factor, higher-order versus bifactor) were excluded on an empirical basis or due to researcher bias, and if model modifications were theoretically driven or applied in an effort to essentially maximize the fit statistics of a given model. In this study, we took precaution against these issues by establishing a consistent set of models and variants based on the extant literature and reviewing modification indices post-hoc. While we consider this a strength of the study, and modification indices suggested that we did not exclude any important alternate models, the inclusion of additional models may have provided further psychometric insight into the Chilean WAIS-IV.

A second issue has to do with the need for continued discussion and investigation regarding the distinctions between the constructs of direct (bifactor) and indirect (higher-order) *g*, as well as other broad factors (indices). The state of intelligence literature strongly conveys a sense of two “camps”, one strongly in favor of higher-order models (e.g., Keith & Reynolds, 2018l; Weiss, Keith, Zhu, & Chen, 2013a; 2013b) and the other strongly in favor of bifactor models (e.g., Cucina & Byle, 2017; Frisby & Beaujean, 2015; Gignac, 2008; Gignac & Watkins, 2013). While this study does not provide sufficient evidence for one perspective over the other, we echo Straffaroni et al.’s (2018) call for continued conversation, and we believe a series of systematic validation studies in samples ranging in age, clinical presentation, and cultural origin could help to elucidate the theoretical underpinnings of general intelligence and its broad factors. For example, an alternate form of the CHC model using ten subtests has been demonstrated in older individuals, ages 70-90 years (Niileksela et al., 2013), and this model could be examined in the Chilean and other versions of the WAIS-IV as well as other intelligence tests (e.g., Kaufman, Johnson, & Liu, 2008). Until then, the findings from this study add to the literature calling for caution when clinically interpreting index scores (Canivez & Kush, 2013; Gignac & Watkins, 2013; Watkins, Dombrowski, & Canivez; 2018). Finally, future studies are needed to further examine intelligence constructs and the CHC model in relation to other neuropsychological constructs, such as executive functioning (Duggan & Garcia-Barrera, 2015; Floyd, Bergeron, Hamilton, & Parra, 2010;

Hoelzle, 2008; Jewsbury, Bowden, & Strauss, 2015; Ortiz, 2015; Schneider & McGrew, 2018; and van Aken, Kessels, Wingbermühle, Wiltink, van der Heijden, & Egger, 2014).

Finally, this study contributes important findings to the under-researched area of cross-cultural construct validity (Helms, 1992). The index with the highest factor loading was Gf, which suggests that Gf may be over factored and is consistent with the literature demonstrating potential redundancies in Gf and *g* (see Cavinez, Dombrowski, & Watkins, 2018). Subsequently lower factor loadings were found for Gv/Gc, Gsm, and Gs. Comparing factor loadings of our best-fitting models to similar models fit with the United States standardization data show that highest factor loadings across higher-order and bifactor variants were found most consistently in Gc subtests for the Chilean WAIS-IV, and were more variable (ranging across Gc, Gv, Gf) in United States Models (Gignac, 2014; also see Niikesla et al., 2013 and Staffaroni et al., 2018). While few conclusive determinations about underlying construct validity differences can be made from these comparisons, the results from this study contribute another (albeit small) piece of information to the accumulating literature suggesting stronger cross-cultural differences in nonverbal tests and dispelling the myth of intelligence test universalism (Brickman, Cabo, & Manly;, 2006; Cores et al., 2015; Daugherty, Puente, Fasfous, Hidalgo-Ruzzante, & Pérez-Garcia, 2017; Flores et al., 2017; Gasquoine, 1999; O'Bryant, Edwards, Johnson, Hall, Gamboa, & O'jile, 2018; Olson & Jacobson, 2014; Rivera Mindt et al., 2019; Rivera Mindt, Byrd, Saez, & Manly, 2010; Rosselli & Ardila, 2003). Future research dedicated to systematic evaluation of cross-cultural construct validity in intelligence and other cognitive tests is vital.

Summary

This study in the Chilean WAIS-IV adds to the scarce literature investigating alternative WAIS-IV factor models in cross-cultural contexts. It adds new information demonstrating that arithmetic is not suitable for cross-loading on VCI/Gc in the Chilean WAIS-IV. These results are consistent with the growing literature supporting a five-factor CHC model as a potentially more adequate description of

Chilean WAIS-IV data. With regards to factor structure, the fit statistics favored the bifactor models; however, the implications for this finding are not yet clear. In particular, more research is needed consistently applying transformations and more complex methods (e.g., Schmid-Leiman transformation; Yang et al., 2017) to make higher-order and bifactor models directly comparable (Gignac, 2016). While results have implications for the clinical interpretation of the Chilean WAIS-IV (e.g., conceptualizing full-scale intelligence quotient as a breadth factor rather than a superordinate factor of index-level abilities), further studies examining the clinical utility and cross-cultural replicability of WAIS-IV bifactor and CHC models are needed.

Chapter 3. Developing Short Forms of the Chilean adaptation of the WAIS-IV for Intellectual Screening*

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*Manuscript to be submitted to *Psychological Assessment.*

All work in this chapter was conceived of and carried out by me, with the exception of the critical feedback incorporated into the execution of some analyses and the writing of this manuscript by my other committee members.

Abstract

Objective: The recent publication of the Chilean adaptation of the WAIS-IV (Wechsler, 2013) has contributed to ongoing efforts to provide more psychometric instruments culturally appropriate for regions in South America. While not all assessment situations necessitate administration of the full WAIS and calculation of a full-scale intelligence quotient (FSIQ), there is virtually no published research on WAIS-IV short forms for estimating IQ in Spanish-speaking individuals. Additionally, IQ short forms in the literature are often criticized for poor theoretical foundation and psychometric relationship to the parent instrument. Thus, this study aimed to systematically derive the most psychometrically robust short forms using two, three, four, and five subtests for the Chilean WAIS-IV. **Method:** The original standardization data (N=887) was used to derived short forms based on a thorough set of criteria and methods, adapted from those described by Smith et al. (2000), including evaluation of reliability, validity, factor structure and construct consistency, and clinical correspondence. **Results:** We reduced the 4,928 possible short form combinations down to the 28 best short forms (7 two-subtests versions, 7 three-subtest versions, 8 four-subtest versions, and 6 five-subtests versions) consistent with traditional Wechsler and Cattell-Horn-Carroll models of intelligence. Tables for estimating IQs and their 95% confidence intervals using these short forms were also produced using linear scaling ("Tellegen and Briggs Procedure", 1967). **Discussion:** This paper provides a psychometrically robust set of IQ estimation tools using the Chilean WAIS-IV, an instrument widely used throughout Latin America. While further research is needed to establish the external validity of these measures, and caution must be used when implementing short forms, these screening tools help expand empirically supported instrument selection in Latin America and contribute to the pressing call for the development of international assessment tools and research.

Introduction

The Wechsler Adult Intelligence Scale-Fourth Edition (WAIS-IV; Wechsler, 2008b), a measure of intelligence and global cognitive ability, is one of the most popular assessment instruments internationally (Rabin, Paolillo, & Barr, 2016; Elbulok-Charcape, Rabin, Spadaccini, & Barr, 2014). The WAIS-IV is made up of 10 core subtests and five supplementary tests, which yield the Full-Scale Intelligence Quotient (FSIQ) and other index scores, including the Verbal Comprehension Index (VCI), Perceptual Reasoning Index (PRI), Working Memory Index (WMI), and the Processing Speed Index (PSI). According to the WAIS-IV administration manual, the estimated administration time to obtain the FSIQ ranges from 65 to 90 minutes; yet that figure can increase notably when assessing clinical populations (Ryan, Lopez, & Werth, 1998). Not all assessment scenarios, however, call for a precise IQ and the detailed information generated by a comprehensive WAIS-IV administration. In fact, a shortened IQ estimate based on fewer subtests often is all that is needed in many clinical and research scenarios, such as global intelligence screening, re-evaluations, and monitoring (Christensen, Girard, & Bagby, 2007; Sattler & Ryan, 2009). In assessments of individuals with sensory, motor, physical, and/or psychological constraints, full assessment may simply not be feasible or ethical (Crawford, Allum, & Kinion, 2008; Sattler & Ryan, 2009). Furthermore, there have been increasing demands on psychologist to provide more efficient care within the broader healthcare system (Eisman et al., 2000; Sanchez & Turner, 2003).

In response to inherent demand, numerous WAIS short forms have been developed for the current and prior versions of the WAIS. However, there is no simple procedure for deciding the content of a short form given the enormous amount of potential subtest combinations, and a myriad of short forms have ranged from one to nine subtests using methods including proration (Meyers, Zellinger, Kockler, Wagner, & Miller, 2013), regression (Crawford & Howell, 1998; Denney, Ringe, & Lacritz, 2015), and linear scaling (also known as linear equating, the deviation quotient method, or the "Tellegen & Briggs procedure", Tellegen & Briggs, 1967; Silverstein, 1990). WAIS short forms include those for the

WAIS-IV (Batchelor & Meyers, 2013; Bulzacka et al., 2016; Denney et al., 2015; Girard, Axelrod, Patel, & Crawford, 2015; Meyers et al., 2013; Olivier et al., 2014; Ryan, Kreiner, Gontkovsky, & Glass Umfleet; 2015; Sattler & Ryan, 2009; Wechsler, 2008b, 2008c), the Wechsler Adult Intelligence Scale-Third Edition (**WAIS-III;** Axelrod, Ryan, & Ward, 2001; Blyler, Gold, Iannone, & Buchanan, 2000; Christensen, Girard, & Bagby, 2007; Clara, 2000; Crawford, Allum, & Kinion, 2008; Donnell, Pliskin, Holdnack, Axelrod, & Randolph 2007; Fuentes-Durá, Romero-Peris, Dasí-Vivó, & Ruiz-Ruiz, 2010; Girard, Axelrod, & Wilkins, 2010; Pilgrim, Meyers, Bayless, & Whetstone, 1999; Reid-Arndt, Allen, & Schopp, 2011; Ringe, Saine, Lacritz, Hynan, & Cullum, 2002; Schoenberg, Duff, Dorfman, & Adams, 2004; van Duijvenbode, Didden, van den Hazel, & Engels, 2016; van Ool et al., 2017; Wagner, Pawlowski, Yates, Camey, & Trentini, 2010; Wechsler, 1997), the Wechsler Adult Intelligence Scale-Revised Edition (**WAIS-R;** Kaufman, Ishikuma, & Kaufman-Packer, 1991; McPherson, Buckwalter, Tingus, Betz, & Black, 2000; Mendella, McFadden, Regan, & Medlock, 2000; Miller, Steiner, & Goldberg, 1996; Ryan & Ward, 1999; Satterfield, Martin, & Leiker, 1994; Silverstein, 1982; Silverstein, 1985; Ward, 1990), and not strictly short forms, but related, the first and second editions of the Wechsler Abbreviated Scale of Intelligence (**WASI and WASI-II;** Wechsler, 1999; Wechsler, 2011).

Wechsler short forms remain the most frequently employed type of brief intelligence testing (Thompson, LoBello, Atkinson, Chisholm, & Ryan, 2004) and research demonstrates their utility in non-clinical (Meyers et al., 2013; Sattler & Ryan, 2009) and clinical samples (Bulzacka et al., 2016; Denney et al., 2015; Girard et al., 2015; Oliver et al., 2014; Ryan et al., 2015). Their popularity has been attributed to numerous factors, including the high cost of testing materials, familiarity with and preference for Wechsler tests, and easy accessibility, implementation and flexibility to expand to full intelligence assessment when needed (Girard et al., 2010; Thompson et al, 2004; Wright et al., 2017).

While the diversity, flexibility, and brevity of WAIS short forms make them appealing, development of short forms creates many psychometric challenges. Essentially, with the elimination of each subtest, the psychometric quality of the instrument, and thus the ability to accurately and reliably estimate IQ decreases. Short forms have been highly criticized for not providing adequate psychometric evidence and justification (e.g., statistical problems associated with validity coefficients when using short form data acquired from full administration, acceptable cost versus benefit), and recommendations have ranged from cautioned short form use to outright abandonment in favor of well-supported abbreviated intelligence tests (Anderson, 2016; Axelrod, 2002; Kaufman & Kaufman, 2001; Levy, 1968; Silverstein, 1990; Smith, McCarthy, & Anderson, 2000; Tellegen & Briggs, 1967; Wymer, Rayls, & Wagner, 2003).

Noticeably absent from these criticisms of short forms, however, are broader conversations surrounding the cultural psychology (Ardila, 1995; Brickman, Cabo, & Manly, 2006; Pedraza & Mungas, 2008) implications of calls to abandon short forms in favor of new instrument development (e.g., standalone abbreviated intelligence tests). In fact, lack of assessment tools and norms is a top barrier affecting cultural neuropsychologists, especially in Latinx populations (Arango-Lasprilla, Stevens, Morlett Paredes, Ardila, & Rivera, 2017; Fernandez, 2019; Fernandez, Ferreres, Morlett-Paredes, Rivera, & Arango-Lasprilla, 2016; Fonseca-Aguilar et al., 2015; Olabarrieta-Landa et al., 2016; Echemendia & Harris, 2004; Echemendia, Harris, Congett, Diaz, & Puente, 1997; Manly, 2008; Suchy, 2016). This is highly problematic given the profession’s ethical obligation to provide services to culturally diverse populations, and psychologists have been urged to stop waiting for ideals and to immediately produce practical solutions that meet the significant demand (American Educational Research Association, American Psychological Association [APA], & National Council on Measurement in Education, 2014; APA, 2003, 2017; Clauss-Ehlers, Chiriboga, Hunter, & Roysircar, 2019; Marsella, 1998; Morgan-Consoli, Inman, Bullock, & Nolan, 2018; Suzuki & Ponterotto, 2008; Uzzell, Ponton, Ardila, 2007).

Even within the large body of WAIS short forms research there is surprisingly little cross-cultural research available, with the vast majority of Wechsler short forms developed and researched in North

America. For Spanish-language assessment, no WAIS-IV short forms, to our knowledge have been published, and the little research on WAIS-III short forms (e.g., Fuentes-Durá et al., 2010; Úbeda, Fuentes, & Dasí, 2016) has been rendered obsolete by the lack of psychometric support and calls for discontinued use of these versions of the WAIS (i.e., Escala de Inteligencia de Wechsler para Adultos-Tercera Edición Spainish, Puerto Rican and Mexican versions; Thaler & Jones-Forrester, 2013; von Thomsen, Gallup, Llorente, 2008). While there are some Spanish-language brief intelligence instruments (e.g., Kaufman & Kaufman, 2004; Lange et al, 2012; Santamaría, Arribas, Pereña, & Seisdedos, 2005; Santamaría & Fernández Pinto, 2009), they are not well known or studied and, in our experience, psychologists working Latin American settings tend to favor the more-established WAIS-IV. Pragmatically speaking, calls for new instrument development are idealistic, but unhelpful in meeting the current needs of cultural psychologists working with limited resources. Thus, while psychologists continue developing new culturally appropriate assessment tools, a strong argument can be made for the use of short forms in countries beyond the United States since the WAIS-IV has been adapted into at least 26 cultural and language versions (Pearson Clinical, 2019) and is one of the most widely used instruments in the world (Rabin et al., 2016).

Rather than rejecting short forms in their entirety, Smith et al. (2000) produced a set of guidelines addressing reliability and validity issues typically ignored by short form developers that, if “followed, then researchers will be in a strong position to argue that their short form is a reliable, valid alternative to a fuller, more comprehensive assessment (p. 110).” These guidelines include recommendations on demonstrating reliability, validity, overlapping variance with the full instrument, preserved classification rates, and factor structure consistency. In this paper, we adapted these guidelines to expand the selection of Latinx, low-cost, easy-to-implement psychometric tools for intelligence screening by developing short forms for the Chilean version of the WAIS-IV (Wechsler, 2013) using the original standardization data. The main goal of this study was to rigorously and systematically establish a set of the best two-, three-, four-, and five-subtest Chilean WAIS-IV short forms that demonstrate reliability, validity, and consistency of factor structure, and consistent of clinical classification with the full instrument using a linear scaling approach. Given the psychometric strength of the Chilean WAIS-IV (Wechsler, 2013; Rosas et al., 2014; Duggan & Garcia-Barrera, 2019) and research demonstrating the feasibility of robust WAIS short form development (as reviewed above), we hypothesized that we would be able to develop the projected set of psychometrically supported and clinically useful Chilean WAIS-IV short forms.

Methods

Measures

The Chilean version of the WAIS-IV (Wechsler, 2013; Rosas et al., 2014) is an adaptation of the Spanish WAIS-IV (Wechsler, 2012a), which was the first Spanish-language test adapted from the original United States WAIS-IV (Wechsler, 2008b, 2008c). The Chilean WAIS-IV includes the same subtests, items, and score structure as the Spanish and United States WAIS-IV, with only minor cultural adaptations to item content/scoring. Consequently, it has 10 core subtests (Similarities [SI], Vocabulary [VC], Information [IN], Block Design [BD], Matrix Reasoning [MR], Visual Puzzles [VP], Digit Span [DS], Arithmetic [AR], Symbol Search [SS], and Coding [CD]) and five supplemental subtests (Comprehension [CO], Figure Weights [FW], Picture Completion [PC], Letter-Number Sequencing [LN], and Cancellation [CA]), which yield four index scores (Verbal Comprehension Index [VCI], Perceptual Reasoning Index [PRI], Working Memory Index [WMI], and Processing Speed Index [PSI]) and a Full-Scale Intelligence Quotient (FSIQ). According to the Chilean WAIS-IV technical data, internal Pearson consistency reliability for the test as whole (FSIQ) is 0.941, with mean index reliability coefficients of 0.951 for VCI, 0.874 for PRI, 0.912 for WMI, and 0.854 for PSI, and subtest reliabilities ranging from 0.733 to 0.925. These reliabilities are comparable to those reported in the United States WAIS-IV manual (mean reliability for United States FSIQ = 0.98, VCI = 0.96, PRI = 0.95, WMI = 0.94, PSI = 0.90, and subtests ranging from 0.78

to 0.94). Additional technical information about the Chilean WAIS-IV is provided in the administration manual (Wechsler, 2013) and accompanying technical information (Rosas et al., 2014; Duggan & Garcia-Barrera, 2019).

Participants

This study used the original Chilean WAIS-IV standardization sample data, which comprises 887 Chilean, Spanish-speaking individuals ages 16:00 to 90:00 representative of the general Chilean population (M_{age}=47.17, SD_{age}=23.62, 52% women; Wechsler, 2013; Rosas et al., 2014). Since individuals aged 70 years and older were only administered 12 of the 15 WAIS-IV subtests (FW, LN, and CA omitted), only 672 individuals completed all 15 subtests (M_{age}=36.93, SD_{age}=17.12, 50.45% women). Analyses including FW, LN and CA were adjusted accordingly for this difference (Wechsler, 2013; Rosas et al., 2014).

Procedure for Establishing Best Short Forms

Data was used with permission from the standardization team and approved by the Human Research Ethics Board at the University of Victoria (Protocol Numbers 18-129). The guidelines outlined by Smith et al. (2000) were adapted to establish the following rigorous and iterative approach for determining the best two-, three-, four-, and five-subtest short forms of the full Chilean WAIS-IV. The entire short form derivation process is depicted in Figure 3.1 and described step-by-step below. Whenever possible, the most stringent criteria were applied in the short form development to ensure psychometric strength. All statistics were calculated using Microsoft Excel and SPSS Statistics Version 25 (IBM, 2017) and confirmatory factor analysis was conducted in Mplus Version 8 (Muthén & Muthén, 1998-2017). Standardized subtest scores were used for analysis and the original correlation matrix for the Chilean WAIS-IV standardization sample is reported by Rosas et al. (2014). All statistics pertaining to the factor structure of the full WAIS-IV, as referred to below, were estimated in a separate study by Duggan & Garcia-Barrera (2019) and are summarized in Supplemental Table 3.1.

Step 1: Evaluate reliability and validity of all short forms. First, reliability coefficients (r_{ss}) and validity (r) coefficients (part-whole correlations) for all subtest combinations (105 two-subtest combinations, 455 three-subtest combinations, 1365 four-subtest combinations, and 3003 five-subtest combinations) were calculated per the methods outlined by Tellegen & Briggs (1967) and Sattler & Ryan (2009, p. 284) as follows:

$$r_{ss} = \frac{\Sigma r_{ii} + 2\Sigma r_{ij}}{k + 2\Sigma r_{ij}}$$

where: r_{ss} = reliability of the short form
r_{ii} = reliability of subtest i
r_{ij} = correlation between any subtests i and j
k = number of component subtests

$$r'_{pw} = \frac{\Sigma\Sigma r_{jl}}{\sqrt{k + 2\Sigma r_{ij}}\sqrt{t + 2\Sigma r_{lm}}}$$

where: r'_{pw} = modified coefficient of correlation between the composite part and the composite whole
r_{jl} = correlation between any subtest j included in the part and any subtest l included in the whole, where any included correlation between a subtest and itself is represented by its reliability coefficient
r_{ij} = correlation between subtests i and j
r_{lm} = correlation between subtests i and m
k = number of component subtests
t = number of tests included in the whole

Since the estimation methods are prone to redundant error variance because the subtests are embedded within the full-scale instrument, correlations for estimating validity coefficients were corrected using Levy's (1967) method, as shown in the equation above (Girard & Christensen, 2008). Note that classification of subtests as core or supplemental is based on the psychometrics and tradition of the United States WAIS-IV (Wechsler, 2008c) and research has demonstrated that subtests may not have consistent properties across different cultural versions of the WAIS-IV (Duggan et al., 2018; Duggan & Garcia-Barrera, 2019). Thus, all 15 Chilean WAIS-IV subtests were initially considered as candidates for inclusion in short forms.

Reliability and validity coefficients of all possible short forms were used to evaluate baseline estimates (Figure 3.1, Row 1). While coefficients above 0.70 are typically deemed as good (Hair, Black, Babin, & Anderson, 2010; Kline, 2013; Smith et al., 2000, values considered acceptable for short for selection are higher, with reliabilities above 0.90 and validity coefficients above 0.82 (Donders &. Axelrod, 2002). As a result, any short form combination falling below these values (r_{ss} < 0.90 and r < 0.82) was eliminated (Figure 3.1, Row 2).

Steps 2-4: Reduce short form combinations through a theoretical and empirical basis. Next, we reduced that number of potential short form combinations by using a series of steps, guided by the principles outlined by Smith et al. (2000), to ensure theoretical and empirical alignment with contemporary intelligence theory. As studies investigating WAIS-IV factor structure provide robust support for a breadth factor (i.e., full-scale intelligence quotient [FSIQ]/general intelligence [*g*]), but less consistent support for the clinical interpretation of index scores (Canivez & Kush, 2013; Duggan & Garcia-Barrera, 2019; Gignac & Watkins, 2013; Watkins, Dombrowski, & Canivez; 2018), the focus of short form development in this study was only to provide the best estimate of FSIQ as possible.

Step 2: Eliminate short forms with poor theoretical alignment that inadequately preserve and prioritize content domains. As extensively discussed by Smith et al. (2000), Silverstein (1990) and others, short forms must preserve the content domains represented by the subfactors of the full instrument. For the WAIS-IV, substantial evidence has provided support for both a traditional Wechsler (four-factor) model and a Cattell-Horn-Carroll (CHC, five-factor) model (Duggan & Garcia-Barrera, 2019). The Wechsler model uses the WAIS-IV subtests as indicators of factors representing verbal abilities (Verbal Comprehension Index [VCI] as indicated by SI, VC, IN, and CO), perceptual reasoning abilities (Perceptual Reasoning Index [PRI], as indicated by BD, MR, VP, FW, and PC), working memory abilities (Working Memory Index [WMI], as indicated by DS, AR, and LN), and speed of cognitive processing (Processing Speed Index [PSI], as indicated by SS, CD, and CA), which are then combined to indicate overall intellectual ability (FSIQ). The CHC model as applied to the WAIS-IV is similar to the Wechsler model, but a fifth factor is created by separating PRI into two factors (Benson et al., 2010). Thus VCI is akin to crystallized intelligence (Gc), WMI akin to short-term memory (Gsm), and PSI akin to processing speed (Gs), and PRI is split into fluid intelligence (Gf, as indicated by MR, AR, and FW) and visual processing (Gv, as indicated by BD, VP, and PC). As such, content domains in the Wechsler model comprise VCI, PRI, WMI, and PSI, while content domains in the CHC model comprise Gc, Gf, Gv, Gsm, and Gs.

Without conclusive evidence in favor of one model over the other, both Wechsler and CHC models were used to guide inclusion and exclusion of subtests in relation to content domains. While many short forms not aligning well with intelligence theory should theoretically be eliminated in the first derivation step (eliminating combinations with insufficient reliability and validity), an additional screening step is needed to ensure surviving combinations adequately preserve and prioritize content domains. Suitable combinations meeting this criterion vary greatly based on the number of the tests in the short form. Here we employed the following guidelines. First, no short form should be comprised entirely of subtests from the same content domain (e.g., the three-subtest combination SI, VC, and IN consists of only VCI/Gc subtests and thus would not be suitable). Second, subtest combinations must prioritize the most robust content domain indicators of FSIQ, as evidenced by factor analytic evidence. In the Chilean WAIS-IV, Duggan & Garcia-Barrera (2019) found the most robust Wechsler indicator of FSIQ was PRI, followed by VCI, WMI, and PSI. For CHC models, the most robust indicator of *g* was Gf, followed by Gv, Gc, Gsm, and Gs.

Based on these principals, the following criteria were established. For two-subtest short forms: (1) two content domains must be represented, (2) a test of PRI/Gf/Gv must be included, (3) no tests of PSI/Gs, (3) AR (Gf) cannot be combined with DS or LN (WMI/Gsm). For three- and four-subtest short forms: (1) two or three content domains must be represented (or in the CHC model Gv and Gf cannot be solely represented), (2) WMI/Gsm and PSI/Gs cannot be the only two domains represented, (3) VCI/Gc and PSI/Gs each cannot be represented twice, (4) WMI/Gsm cannot be represented twice, with the exception of AR (which can also be considered a Gf subtest) as long as it is combined with tests of

PRI/Gv *and* VCI/Gc, (5) VCI/PRI cannot be represented 3 times. For five-subtest short forms: (1) at least three content domains must be represented (2) a domain cannot be represented with all of its subtests (or in the CHC model Gv and Gf cannot be solely represented), (3) WMI/Gsm and PSI/Gs combined can only be represented by two subtests, with the exception of AR (if considered a Gf subtest). Short forms candidates not aligning with the Wechsler or the CHC model based on these criteria were eliminated from further consideration (Figure 3.1, Row 3).

Step 3: Eliminate non-robust indicators of FSIQ. Factor loadings for the Chilean WAIS-IV were previously estimated in our study examining its alternative factor structures (Duggan & Garcia-Barrera, 2019). Since that study provided support for both Wechsler (four-factor) and CHC (five-factor) models, as well as higher-order and bifactor model variants, here we aggregated information across all best study models to inform short form development. Specifically, we averaged factor loadings for each subtest indicator of FSIQ across best models (as computed in Duggan & Garcia-Barrera, 2019 and including the Schmid-Leiman transformation; Schmid & Leiman, 1957) to make higher-order loadings directly comparable to bifactor loadings). These calculations are summarized Supplemental Table 3.1.

The higher a factor loading is, the more it contributes to defining a factor’s dimensionality. Standardized loadings of 0.30 to 0.40 are typically considered reasonably strong, loadings of .70 to .80 are commonly considered very strong, and values of 1.0 represent an optimal, but unlikely level in ‘real-life’ data (Furr & Bacharach, 2014). Sample size and numbers of indicators, however, should also be taken into consideration when interpreting factor loadings. For instance, factors with four or more loading values of 0.60 or greater are deemed reliable, regardless of sample size (Guadagnoli & Velicer, 1988 as cited in Stevens, 2002). Given the variable number of indicators used per factor depending on the models, the intermediate criterion of λ>.60 was selected as the cutoff in this study (Figure 3.1, Row 4).

Step 4: Eliminate short forms with inadequate factor structure consistency. For this step, each set of short form combinations were ranked based on highest mean combined reliability and validity coefficients. The top 25 candidates from each short form version were carried through to the next step, examining factor structure consistency using confirmatory factor analysis (i.e., short forms as indicators of estimates FSIQ; Figure 3.1, Row 5; Supplemental Table 3.2). Models were evaluated using chi-square (χ^2) test, comparative fit index (CFI), Tucker-Lewis index (TLI), and root mean square error of approximation (RMSEA), The established cutoff criteria were used for model comparison (i.e., optimal CFI/TLI $\geq$ 0.95, adequate RMSEA < 0.08, χ^2 closer to zero the better; Hu & Bentler, 1999; Jackson, Gillaspy, & Purc-Stephenson, 2009; Marsh, Balla, & McDonald, 1988; Brone & Cudek, 1993 as cited in Schermelleh-Engel, Moosbrugger, & Müller, 2003; Schreiber, Nora, Stage, Barlow, & King, 2006). Factor loadings of <0.6 were again deemed inadequate. Any models with one or more of these parameters below the established cutoffs were excluded from further consideration (Figure 3.1, Row 6; Supplemental Table 3.3). Note that two-subtest short form models have negative degrees of freedom and three-subtest short form models have zero degrees of freedom. Thus, fit statistics for these short forms cannot be estimated for this and a number of other statistical reasons and this method cannot be used to reduce two-subtest and three-subtest short forms.

Step 5: Estimate IQ with linear scaling (the Tellegen & Briggs Procedure). Linear scaling takes subtest score-combinations and rescales them using deviation quotients (Tellegen & Briggs, 1967). This was the same method used in obtaining the original deviation quotients in the WAIS and was used here to generate estimated IQ for the best remaining two-, three-, four-, and five-subtest short forms as identified through the methods above. Specifically, composites of subtest scales scores are linearly scaled into deviation quotients with mean of 100 and standard deviation of 15 per the following formula (Tellegen & Briggs, 1967; Sattler & Ryan 2009, p. 283):

$$\text{Estimated IQ} = \left(\frac{15}{S_c}\right)(X_c - M_c) + 100$$

where: $S_c = S_s\sqrt{n + 2\sum r_{jk}}$ (standard deviation of composite score)
X_c = composite score (sum of subtest scaled scores in the short form)
M_c = normative mean, which is equal to 10_n
S_s = subtest standard deviation, which is equal to 3
n = number of component subtests
$\sum r_{jk}$ = sum of the correlations between component subtests

These IQ estimates were used to generate the norms tables for the final set of short forms. As part of this process, we also calculated 95% confidence intervals (CIs) for all scores (Oosterhuis, van der Ark, & Sijtsma, 2017) and well as the reliable and unusual ranges for the scaled scores (Sattler & Ryan, 2009).

Step 6: Eliminate short forms with inadequately preserved clinical content and classification. To determine agreement between true and estimated IQs, we calculated their difference scores and evaluated them based on the percentage of scores falling within ±2, ±5, and ±10 points of the FSIQ. These values represent approximately one standard error of measurement (SEM), two standards of measurement, and one standard deviation (SD) for two-subtest for forms. Note that for five-subtest short forms, these values are approximately ±5 points (1 SEM), ±10 points (2 SEM), and ±14 points (1 SD). While these values vary from those for the full instrument (±3 points = 1 SEM, ±6 = 2 SEM, and ±15 points = 1 SD), the two-subtest values capture the most stringent parameters for evaluating clinical classification. Therefore, for consistency sake, we evaluated all short forms using these values.

Further, an estimated IQ measure must accurately classify individuals in as close to the same way as possible as would be obtained on the original WAIS-IV measure. Clinical classifications for FSIQ range from: $\leq$ 69 = very low, 70-79 = borderline, 80-89 = low average, 90-109 = average, 110-119 = high average, 120-129 = very superior, to $\geq$ 130 = very superior. Clinical classification accuracy was examined using percentage of individuals falling within same classification levels, as well as rates and magnitudes of classification errors among individuals (i.e., percentage of individuals falling within one-to-six clinical classification levels lower or higher). Short forms that did not adequate demonstrate preserved clinical classification, defined as producing fewer than 80% of estimated IQs within 1 SD of the true FSIQ and producing any estimated IQ more than 2 clinical classifications different (with no more than 5% of scores 2 classifications different), were eliminated (Figure 3.1, Row 6).

Step 7: Eliminate any further short forms based on cost-benefit justification and pragmatic considerations. Since the goal of a WAIS-IV short form is to provide the most accurate IQ estimation in as little time as possible (Silverstein, 1990), final short form candidates were reviewed to ensure they would yield total administration times that would justify the cost of lower reliability and validity than the full instrument (Jeyakumar, Warriner, Raval, & Ahmad, 2004). Similarly, we reviewed the remaining short forms for any combinations heavily reliant on rarely used subtests or clinical unusual combinations. Any short forms not meeting these guidelines were considered for elimination or notated as not ideal.

Results

Overall, all 4,928 combinations of two-, three-, four-, and five-subtests short forms of the full Chilean WAIS-IV were reduced to the combinations with the best reliability, validity, content structure preservation, and clinical classification preservation using the derivation process adapted from Smith et al. (200), as depicted in Figure 3.1.

Short Form Derivation Process

All initial Pearson reliability and validity coefficients for all possible short-forms (N=4,928) fell above the minimum criteria of 0.7 (two-subtest r_{ss} = 0.822 to 0.952, r = 0.762 to 0.856; three-subtest r_{ss} = 0.879 to 0.958, r = 0.804 to 0.906; four-subtest r_{ss} = 0.911 to 0.964, r = 0.855 to 0.930; five-subtest r_{ss} = 0.894 to 0.950, r = 0.890 to 0.943). Results across all short form versions are reported here and depicted in Figure 3.1, column 5. Ultimately, 455 combinations were eliminated due to having reliability or validity coefficients below the acceptable cutoff (new n = 4,473). Next, remaining combinations were examined for alignment with Wechsler and CHC model structure using the unique criteria developed short form version. A total of 1,484 combinations did not adequately preserve content in alignment with Wechsler and CHC theory, resulting in a total new *n* of 2,989 remaining short combinations. Next, the short form derivation process calls for elimination of any subtests found to be poor indicators of FSIQ/*g*. As comprehensive examination of best factor structures of the Chilean WAIS-IV was done in a separate study (Duggan & Garcia-Barrera, 2019), we used those results that to guide selection of poor indicators in this step. Thus, combinations containing subtests with loadings consistently falling below the established cutoff criteria across all models (AR, FW, CD, and CA; Supplemental Table 3.1, new *n* = 676). Remaining short form candidates were then ranked by highest mean combined reliability and validity coefficients and the top 25 for each short form version were retained for further short form derivation (new *n* = 90). CFA was then used to examine factor structure consistency of the remaining 90 short form candidates. Since fit statistics for two-subtest and three-subtest models cannot be estimated (due to a number of statistical issues, including not enough degrees of freedom), only factor loadings were estimated for three-subtest models and full CFAs were conducted for four- and five-subtest short forms. All models converged normally, and fit statistics were generally strong; therefore, the decision to use the most stringent cutoff criteria across all fit statistics (as detailed above) was supported by the data (i.e., we were not being overly stringent and eliminating too many short forms from consideration). Overall, 32 combinations fell below the CFA cutoff criteria and were eliminated (new *n* = 58).

Linear scaling was used to produce tables estimating IQ with 95% CI intervals for the remaining 59 short form combinations. Thirty of these combinations did not meet the clinical classification criteria, with more than 20% of the difference scores between estimated IQ and true FSIQ exceeding 10 points and several combinations producing estimated IQs falling three-to-six clinical classification levels above or below the true FSIQ. Qualitative analysis of these subtest combinations did not indicate any irregular patterns (i.e., subtests or combinations of subtests systematically leading to inaccurate scores and mis-classification). This yielded the 28 best short forms for the Chilean WAIS-IV, as described below. These subtests are also presented in Tables 3.1-3.5 in approximate order of recommended use, based on a combined reliability, validity, and clinical consistency factors.

Two-Subtest Short Forms

Through our iterative short form derivation process, we reduced the 105 possible two-subtest combinations to seven best combinations (Figure 3.1, Column 1). Subtests either comprised those aligned with Wechsler forms (consisting of a VCI/Gc and a PRI/Gf /Gv test, similar to Wechsler, 2008b, 2008c) or CHC forms (consisting of VCI/Gc or PRI/Gf/Gv and a WMI/Gsm test). These combinations most commonly included IN, VC, MR, and DS. None of the combinations with SI or BD survived to be included in the very best combinations. Overall, these two-subtest short forms were deemed clinically pragmatic and efficient. Together they have a mean Pearson reliability coefficient of 0.930 and validity coefficient of 0.857 (Table 3.1). These short forms on average produced estimated IQs that were within two points (approximately 1 SEM) of the true FSIQ 25% of the time, within 5 points (approximately 2 SEM) 52% of the time, and within 10 points (1 SD) 81% of the time. Additionally, on average, 57% of the estimated IQs produced by these short forms fell within the same clinical classification as the true FSIQ and 36% fell within one clinical classification above or below the true FSIQ. Only 3% of estimated IQs fell within 2 clinical classifications above or below the true FSIQ, and per the inclusion criteria, none of the estimated IQs fell beyond 2 clinical classifications of the true mean. The information needed to calculate estimated IQs and 95% CI intervals for these two-subtest short-forms is presented in Table 3.2.

Three-Subtest Short Forms

Overall, the 455 possible three-subtest short forms were reduced to the seven best combinations (Figure 3.1, Column 2), six containing only core subtests (including SI, VC, IN, MR, VP, and DS) and one containing a supplemental subtest (LN). Most of these short forms conceptually aligned with the Wechsler model (one verbal, one perceptual reasoning, and one working memory subtest), while only one combination conceptually aligned with the CHC model (one Gf, one Gv, and one Gc test) met all the criteria to be retained through the derivation process. These short forms were deemed clinically pragmatic and efficient; thus, no additional combinations were eliminated. The seven best three-subtest short forms have a mean Pearson reliability coefficient of 0.943 and validity coefficient of 0.894. Looking at the average accuracy of the estimated IQs, 32% were within 2 points of the true FSIQ, 56% were within 5 points of the true FSIQ, and 92% were within 10 points of the true FSIQ. Clinical classification of the estimated IQs fell within the same clinical classification of the true FSIQ 65% of the time. 34% of the estimated IQs were one clinical classification above or below the true FSIQ and 1% were 2 clinical classifications above or below the true FSIQ. The information needed to calculate estimated IQs and 95% CI intervals for these three-subtest short-forms is presented in Table 3.3.

Four-Subtest Short Forms

Of the 1,365 possible combinations, a total of eight met all of the derivation criteria to be retained as the best four-subtest short forms (Figure 3.1, Column 3). Five combinations used only core subtests (including VC, IN, SI, MR, VP) and three combinations also used a supplemental subtest (LN). Four of these combinations were aligned with the Wechsler model (two verbal subtests, one perceptual reasoning subtest, and one working memory subtest), while four were more consistent with a CHC model (one subtest each from Gf, Gv, Gc, and Gsm). While three of the final combinations contained a supplemental subtest, they were retained given the findings supporting the robustness of these subtests (as presented above and discussed further below). The mean Pearson reliability coefficient for these short forms was .953 and the mean validity coefficient was 0.921. On average, four-subtest estimated IQs were accurate within 2 points of the true FSIQ 42% of the time, within 5 points 75% of the time, and within 10 points 96% of the time. Further, 72% of the four-subtests estimated IQs fell within the same clinical classification, while 28% fell within one clinical classification above or below the true FSIQ and 0.70% fell within two clinical classifications above or below the true FSIQ. The information needed to calculate estimated IQs and 95% CI intervals for these four-subtest short-forms is presented in Table 3.4.

Five-Subtest Short Forms

In total, only six of the 3,003 possible five-subtest combinations met all of the derivation criteria to be retained as the best five-subtest short forms (Figure 3.1, Column 4). Two of these combinations contained only core subtests (including SI, VC, IN, BD, MR, VP, DS, and SS) and four combinations also included at least one supplemental subtest (PC, LN). The combinations containing only core subtests were both aligned with the Wechsler model (two verbal subtests and one subtest each from perceptual reasoning, working memory, and processing speed). The combinations including supplemental subtests were all aligned with the CHC model (two Gc subtests and one subtest each from Gf, Gv, and Gsm). Similar to the best four-subtest short forms, while many final combinations contained a supplemental subtest, they were ultimately retained given the findings supporting the robustness of these subtests (as presented above and discussed further below). These best five-subtest short forms have a mean Pearson reliability coefficient of 0.936 and a mean validity coefficient of 0.936. Estimated IQs for these short forms were, on average, within 2 points of the true FSIQ 42% of the time, within 5 points of the true FSIQ 75% of the time, and within 10 points (1 SD) 96% of the time. In terms of clinical classification, 72% of the estimates IQs fell within the same classification level as the true FSIQ, with 28% falling within one classification above or below the true FSIQ, and .7% falling within two classifications above or below the true mean. The information needed to calculate estimated IQs and 95% CI intervals for these five-subtest short-forms is presented in Table 3.5.

Discussion

Developing short forms for international adaptations of the WAIS-IV, one of the most widely used assessment instruments in the world (Rabin, Paolillo, & Barr, 2016), is one solution to help provide cultural psychologists much needed assessment tools (Fernandez, 2019; Manly, 2008; Suchy, 2016). In this study, we rigorously derived a set of the most psychometrically robust estimated IQ short forms for the Chilean WAIS-IV using two, three, four and five subtests. Overall, we found 28 short forms that met our stringent set of criteria that were adapted from Smith el al. (2000) and expanded upon in this study to further emphasize factor analytic approaches and more recent developments in contemporary intelligence test theory within the WAIS-IV (Duggan & Garcia-Barrera, 2019). These best short forms included four two-subtests versions, seven three-subtest versions, 10 four-subtest versions, and six five-subtests versions. All final short forms had high internal consistency reliabilities (ranging from 0.893 to .960) and validity (part-whole correlation) coefficients (ranging from 0.849 to 0.942). Further, the majority of estimated IQs scores across all short forms had good consistency and clinical classification correspondence with the true FSIQs, though short forms with more tests outperformed shorter versions (e.g., five subtests versus two), and all of these findings were consistent with the other recent WAIS-IV short forms research (Chan & Hua, 2019; Denney et al., 2015; Ryan et al., 2015; van Ool; 2017).

Through the derivation process, some subtests were consistently found as better candidates for short form use than others. Of the verbal/Gc subtests, Vocabulary, Information, and Similarities were the only ones used in the best short forms, with Vocabulary and Information being used almost three times more often than Similarities. Several preliminary short forms contained the supplemental verbal subtest Comprehension; however, they were all eliminated during the factor analysis stage due to being part of models with poor fit. The perceptual reasoning subtests used in the best short forms included Block Design, Visual Puzzles and Picture Completion (Gv subtests in the CHC model) and Matrix Reasoning (a Gf subtest); with Matrix Reasoning being the most frequently used and Block Design most rarely being used. Figure Weights (a perceptual reasoning/Gf subtest) was eliminated due to its consistent poor performance, relative to other subtests, as an indicator of FSIQ/*g* (Duggan & Garcia-Barrera, 2019). Similarly, Arithmetic (often split between perceptual reasoning and working memory in the Wechsler model, and between Gf and Gsm in the CHC model) was also eliminated for consistently underperforming as an indicator of FSIQ/*g*. While this may be surprising to many, considering the longstanding use of Arithmetic in United States WAIS short forms, factor model evidence suggests that

Arithmetic appears to have different psychometric characteristics in the Chilean WAIS-IV (Duggan & Garcia-Barrera, 2019). Additionally, Arithmetic and Figure Weights are often cross-loaded in numerous and inconsistent ways across models, which may suggest that these tests have unusual properties and would likely not best be short-form candidates in the first place (Benson et al., 2010; Duggan & Garcia-Barrera, 2019; Weiss et al, 2013b). As a result, Digit Span and Letter-Number Sequencing were the only working memory/Gsm subtests that were retained throughout the development of the best short forms. Altogether, these findings suggest that Letter-Number Sequencing may be a particularly under-utilized subtest of the Chilean WAIS-IV, given its classification as supplemental (in line with the traditional Wechsler test structure; Wechsler, 2008c; Wechsler, 2013). Finally, the processing speed/Gs subtests were the weakest indicators of FSIQ/*g*, consistent with the factor structure and short form literature, and Symbol Search was the only test with psychometric properties exceeding the cutoff criteria (Chen & Hua, 2019; Denney et al., 2015; Benson, Hulac, Kranzler, 2010; Weiss, Keith, Zhu, & Chen, 2013b).

Unique strengths of this study include its breadth and depth. For studies developing short forms the United States WAIS, it makes sense to only consider inclusion of core subtests, as they were designated as such for their relative psychometric strength. In the Chilean and other adaptations of the WAIS-IV, however, core and supplemental tests have been designated to be consistent with the original WAIS-IV. Given accumulating evidence of psychometric differences between some subtest across different versions of the WAIS-IV (Duggan et al., 2018; Duggan & Garcia-Barrera, 2019), this study gave all 15 subtests equal initial consideration for inclusion in short form combinations. Further, this research design contributes a rich array of information that can ultimately be used to investigate psychometric differences that may contribute to cognitive ability differences seen across different cultural groups (Duggan et al., 2018; Frisby & Beaujean, 2015). The short form derivation process can easily be adapted based on developments in Wechsler and CHC intelligence theory, as well as in response to varying psychometric evidence across WAIS-IV (and other Wechsler intelligence test) adaptations. Despite this comprehensive approach, two commonly used “short forms” were not included in this research study: the General Ability Index (GAI) and the Cognitive Processing Index (CPI), which have not yet been developed for the Chilean WAIS-IV. The GAI (derived only from verbal and perceptual reasoning subtests) and the CPI (derived from working memory and processing speed subtests) are two optional index scores developed for the United States and other versions of the WAIS-IV that provide clinical information helpful for characterizing global abilities and understanding individual patterns of, and discrepancies between cognitive strengths and weaknesses (Wechsler, 2008b, 2008c; Weiss, Saklofske, Coalson, & Raiford, 2010). Given the demonstrated clinical utility of these scores and their newfound mainstay in contemporary WAIS assessment (Drozdick, Holdnack, Salthouse, & Cullum, 2013; Harrison, Glass, Bartles, & Ryan, 2009; Iverson, Holdnack, & Lange, 2013; Lange & Chelune 2006; Wechsler, 2008b, 2008c), it is important for future research to develop the GAI and the CPI for the Chilean and other cultural adaptations of the WAIS-IV.

A second strength of this study was our incorporation of factor analytic evidence through several stages of the derivation process. Past short forms have been criticized for neglecting this important information (Smith et al., 2000), and to our knowledge, only one investigation of WAIS-IV short forms has incorporated a similar factor analysis approach, albeit only in three-subtest short forms of the Taiwanese WAIS-IV (Chen & Hua, 2019). Overall, this study presents a pragmatic set of short-forms with their corresponding estimated IQ tables that are ready for use in future research. Next studies of Chilean WAIS-IV short forms should aim to establish their external in clinical and non-clinical samples, demonstrate their psychometric consistency as standalone instruments (i.e., not administered as part of the whole WAIS-IV as is done in the standardization sample), and demonstrate invariance across sex and age (Silverstein, 1990; Smith et al., 2000). Additional investigation may also evaluate these linear scaling methods against regression methods also often used to develop short forms. Even if provided empirical support of their external validity, in coordination with the reliability, validity, and clinical consistency evidence presented here, we urge clinicians and researchers to use substantial caution when using short forms. Short forms should never be used when a classification is needed for clinical, psychoeducation, legal, or similarly consequential decisions. Additionally, IQs derived from short forms must always be presented as “estimated” and they should not be used when the difference between individual scaled scores exceed the unusual range (as presented in Tables 3.2-3.5).

Despite information always being lost when using a short form, having a strong set of tools to efficiently produce reasonable IQs estimates for screening and research is ultimately expected to provide great benefit to psychologists in Latin America, a region long calling for stronger local articulation of and international integration with psychological science (Benito, 2012). Based on our personal experiences, the Chilean WAIS-IV has become the most widely used intelligence assessment instrument throughout all of Latin America, which is not surprising given that the WAIS-IV has only been developed so far (to our knowledge) for Chile, Colombia, Argentina, and Mexico. Additionally, standalone abbreviated intelligence assessment instruments developed for Latin American populations are very scare and many researchers and clinicians simply do not have enough resources to essentially “catch up” in developing the breadth and depth of test selection in the United States and other countries.

The most important aspect of this paper is the presentation of a set of short forms that are ready to use in research and clinical settings. To use the estimated IQ conversion tables, a practitioner simply follows the following steps:

1. Chose the short form that best suits their research or clinical needs.
2. Administers those select short form tests.
3. Convert the raw tests scores into scaled scores.
4. Look up the sum of the scaled scores in the appropriate table (Table 3.2-3.5) to obtain that individual’s estimated IQ and the 95% CI interval for that estimate.

While numerous short form options are presented in Tables 3.1-3.5, they are listed in approximate order of recommended use, based on a combined reliability, validity, and clinical consistency factors. Practitioners are encouraged to select short forms based on thoughtful consideration of their testing situation (e.g., time, sample characteristics, intended use of the estimated IQ score, potential need for "parallel forms" across multiple testing occasions, etc).

The use of these short forms is illustrated in the following two examples. First, take scores (obtained from an anonymized research database) from a randomly selected 28-year-old woman who was administered the full Chilean WAIS-IV and obtained a FSIQ of 124. Using the first two-subtest short form listed in Table 3.2, we sum her Information and Matrix Reasoning scaled scores (14 and 13, respectively) for a total of 27, which yield an estimated IQ of 120 (116-124 95% CI), a score that is highly consistent with her FSIQ obtained with 10 subtests. As a second example, take a 50-year-old man (also randomly selected from an anonymized research database), who obtained a FSIQ of 102 on the full Chilean WAIS-IV. Using the first four-subtest short form listed in Table 3.4. Summing his Vocabulary, Block Design, Matrix Reasoning, and Digit Span scaled scores (10, 9, 14, and 8, respectively) we get a total of 41, which yields an estimated IQ of 102 (96-106 95% CI); again, highly correspondent with his true FSIQ.

As shown though these examples, the short forms presented in this paper possess significant utility throughout Latin America. For example, they can be used throughout a variety of clinical settings requiring only rough estimation of IQ, such as screening individuals to determine if further testing is warranted, or when testing an individual who cannot tolerate extended testing. In research, often only an estimate IQ is needed to quickly screen for individuals for inclusion/exclusion, or to provide an IQ estimate that will be used as a demographic variable. Ultimately, the rigorous methods used in this paper have produced a set of 28 WAIS-IV short forms (using two-to-five subtests) that have good psychometric strength and are ready for immediate use by psychologists throughout Latin America who have been calling for the development of these much need assessment tools.

Epilogue

Entitled *Diversifying Psychometric Tools for Intelligence Assessment and Screening in Latin America,* the three manuscripts comprising this dissertation shared the theme of producing small, but pragmatic, contribution towards helping close what I refer to as the "cultural neuropsychology gap." While this dissertation particularly focuses on data collected in Colombia and Chile, the frameworks, methods, and results across all three papers extend beyond a narrow population.

Chapter one demonstrated how cultural neuropsychologists can approach ambiguous cross-cultural assessment scenarios in a thorough and empirically supported way. It showed how international data statistics can be quickly referenced to better contextualize an assessment scenario, and it provided useful national and test-level demographics tables, ready for clinicians to reference in their clinical practice. While the paper focused most on the sociocultural effects of education, it briefly highlighted issues surrounding SES, cohort effects, and limitations in ethnic representation. It also pointed to the need for future work in better sample characterization and developing demographically corrected norms for all nations with rich socio-historical diversity. The paper also conducted the largest intelligence norms comparison paper to date, by looking at the interpretive effects of applying WAIS-IV norms from six difference countries (Colombia, Chile, Mexico, Spain, United States, and Canada) in a large sample of Colombian executives. This paper also demonstrated nearly identical concordance between the Colombian and Chilean norms when applied to this sample and it pointed to non-intuitive but critically important underlying index and subtest-level difference between these six versions of the WAIS-IV.

Chapters two and three focused on the psychometrics of the Chilean WAIS-IV, the most widely used intelligence test in Latin America. Chapter two systematically evaluated higher-order and bifactor variants of four-factor (Wechsler) and five-factor (CHC) models in the Chilean-WAIS-IV. Results from this study showed slight cross-loading inconsistencies between the Chilean and the United States WAIS-IV and marginally favored bifactor and CHC models. The paper, however, ultimately provided strong support of both model structures and variants and these results were used to inform chapter three, which used a psychometrically rigorous approach to derive Wechsler and CHC-aligned short forms for the Chilean WAIS-IV that are ready for immediate use by researchers and clinicians.

Together these papers provide easily implementable assessment frameworks and tools available to clinicians and researchers in Latin America. They also outline adaptable methods that can help all cultural neuropsychologists better contextualize their instruments and data in a field that is disproportionately represented by research from the United States. More broadly, these papers subtly raise the issue of potential inconsistencies in underlying construct validity across different adaptations of the WAIS-IV and the myth of universalism, particularly with nonverbal tests. While acculturation is undoubtedly one key element contributing to performance and psychometric differences across populations on the WAIS-IV, the findings in this dissertation (particularly chapter two) provide evidence of potential subtle construct differences between Latinx and North American (and other) populations. While I believe these papers to be good first steps towards making a modest contribution to the field of cultural neuropsychology, the need for more research and instrument development is great. I am hopeful that approaches used in these papers can provide seeds that can be grown through the continued work of cultural neuropsychologists in Latin America and throughout the world.

References

Abdelhamid, G. S. M., Gómez-Benito, J., Abdeltawwab, A. T. M., Abu Bakr, M. H. S., & Kazem, A. M. (2017). Hierarchical Structure of the Wechsler Adult Intelligence Scale–Fourth Edition with an Egyptian Sample. *Journal of Psychoeducational Assessment, online first,* 1-10. doi:10.1177/0734282917732857

Acevedo, A., Loewenstein, D. A., Agrón, J., & Duara, R. (2007). Influence of sociodemographic variables on neuropsychological test performance in Spanish-speaking older adults. *Journal of Clinical and Experimental Neuropsychology, 29*(5), 530-544.

Alfonso, V. C., Flanagan, D. P., & Radwan, S. (2005). The impact of the Cattell-Horn-Carroll theory on test development and interpretation of cognitive and academic abilities. In D. P. Flanagan & P. L. Harrison (Eds.), *Contemporary intellectual assessment: Theories, tests, and issues* (pp. 185-202). New York, NY: Guilford Press.

American Educational Research Association, American Psychological Association (APA), & National Council on Measurement in Education (2014). *Standards for educational and psychological testing.* Washington, DC: American Educational Research Association.

American Psychological Association (APA). (2003). Guidelines on multicultural education, training, research, practice and organizational change for psychologists. *American Psychologist, 58,* 377–402. doi:10.1037/0003-066X.58.5.377

American Psychological Association (APA). (2017). *Ethical principles of psychologists and code of conduct.* Retrieved from http://www.apa.org/ethics/code/ethics-code-2017.pdf

Anastasi, A. (1981). *Differential psychology* (4th ed.). New York: Macmillan.

Anderson, D. S. (2016). Short form or short changes? An example of the impact of brief assessments on clinical decision-making in a neuropsychological case. *Australian Psychologist, 51*(5), 400-404. doi:10.1111/ap.12241

Angoff, W. (1984). Scales, norms, and equivalent score. Princeton, NJ: Educational Testing Service.

Arango-Lasprilla, J. C., Stevens, L., Morlett Paredes, A., Ardilla, A., & Rivera, D. (2016). Profession of neuropsychology in Latin America. *Applied Neuropsychology: Adults, 24*(4), 318-330. doi:10.1080/23279095.2016.1185423

Ardila, A. (1995). Directions of research in cross-cultural neuropsychology. *Journal of Clinical and Experimental Neuropsychology, 17*(1), 143-150. doi:10.1080/13803399508406589

Ardila, A. (1998). A note of caution: Normative neuropsychological test performance: Effects of age, education, gender and ethnicity: A comment on Saykin et al. (1995). *Applied Neuropsychology, 5,* 51–53.

Ardila, A. (2005). Cultural values underlying psychometric cognitive testing. *Neuropsychological Review, 15,* 185–195.

Ardila, A., Ostrosky-Solis, F., Rosselli, M., & Gómez, C. (2000). Age-related cognitive decline during normal aging: The complex effect of education. *Archives of Clinical Neuropsychology, 12*(6), 496-513. doi:10.1016/S0887-6177(99)00040-2

Axelrod, B. N. (2002). Validity of the Wechsler Abbreviated Scale of Intelligence and other very short forms of estimating intellectual functioning. *Assessment, 9*, 17-23. doi:10.1177/1073191102009001003

Axelrod, B. N., Ryan, J. J., & Ward, L. C. (2001). Evaluation of seven-subtest short forms of the Wechsler Adult Intelligence Scale-III in a referred sample. *Archives of Clinical Neuropsychology, 16*(1), 1-8.

Batchelor, E., & Meyers, J. (2013). Estimating WAIS-IV FSIQ using the Barona and Ward 7 short from. *Archives of Clinical Neuropsychology*, *28*, 547-548. doi:10.1093/arclin/act054.81

Bender, H. A., García, A. M., & Barr, W. B. (2010). An interdisciplinary approach to neuropsychological test construction: Perspectives from translation studies. *Journal of the International Neuropsychological Society, 16*(02), 227-232.

Benisz, M., Dumont, R., & Willis, J. O. (2015). From psychometric testing to clinical assessment: Personalities, ideas, and events that shaped David Wechsler’s views of intelligence and its assessment. In S. Goldstein, D. Princiotta, & J. A. Naglieri (Eds.), *Handbook of Intelligence* (pp. 163-179). New York, NY: Springer.

Benito, E. (2012). Psychological science around the world: Latin America. *APS Observer, 25*(4). Retrieved April 1, 2019 from https://www.psychologicalscience.org/observer/psychological-science-around-the-world-latin-america.

Benson, N. F., Beaujean, A. A., McGill, R. J., & Dombrowski, S. C. (2018). Revisiting Carroll's survey of factor-analytic studies: Implications for the clinical assessment of intelligence. *Psychological Assessment, 30*(8), 1028-1038. doi:10.1037/pas0000556

Benson, N., Hulac, D. M., & Kranzler, J. H. (2010). Independent examination of the Wechsler Adult Intelligence Scale-Fourth Edition (WAIS-IV): What does the WAIS-IV measure? *Psychological Assessment, 22*(1), 121-130. doi:10.1037/a0017767

Blyler, C. R., Gold, J. M., Iannon, V. N., & Buchanan, R. W. (2000). Short form of the WAIS-III for use with patients with schizophrenia. *Schizophrenia Research, 46,* 209-215.

Boone, K. B., Victor, T. L., Wen, J., Razani, J., & Pontón, M. (2007). The association between neuropsychological scores and ethnicity, language, and acculturation variables in a large patient population. *Archives of Clinical Neuropsychology, 22*(3), 355-365.

Bouman, Z., Hendriks, M. P. H., Van Der Veld, W. M., Aldenkamp, A. P., & Kessels, R. P. C. (2016). Clinical validation of three short forms of the Dutch Wechsler Memory Scale-Fourth Edition (WMS-IV-NL) in a mixed clinical sample. *Assessment, 23*(3), 386-394. doi:10.1177/1073191115593629

Bowden, S. C., Lange, R. T., Weiss, L. G., & Saklofske, D. H. (2008). Invariance of the measurement model underlying the Wechsler Adult Intelligence Scale-III in the United States and Canada. *Educational and Psychological Measurement, 68,* 1024-1040.

Bowden, S. C., Saklofske, D. H., & Weiss, L. G. (2011). Invariance of the measurement model underlying the Wechsler Adult Intelligence Scale-IV in the United States and Canada. *Educational and Psychological Measurement, 71*(1), 186-199.

Brickman, A. M., Cabo, R., & Manly, J. J. (2006). Ethical issues in cross-cultural neuropsychology. *Applied Neuropsychology, 13*(2), 91-100.

Brown, T. A. (2015). Confirmatory factor analysis for applied research (2nd ed.). New York, NY: The Guilford Press.

Brunner, M., Nagy, G., & Wilhel, O. (2012). A tutorial on hierarchically structure constructs. *Journal of Personality, 80*, 796-846. doi:10.1111/j.1467-6494.2011.00749.x

Buchmann, C., & Hannum, E. (2001). Education and stratification in developing countries: A review of theories and research. *Annual Review of Sociology, 27*, 77-102.

Bulzacka, E., Meyers, J. E., Boyer, L., Le Gloahec, T., Fond, G., Szöke, A., ... & Schürhoff, F. (2016). WAIS-IV seven-subtest short form: validity and clinical use in schizophrenia. *Archives of Clinical Neuropsychology, 31*(8), 915-925.

Buré-Reyes, A., Hidalgo-Ruzzante, N., Vilar-López, R., Gontier, J., Sánchez, L., Pérez-García, M., & Puente, A. E. (2013). Neuropsychological test performance of Spanish speakers: Is performance different across different Spanish-speaking subgroups? *Journal of clinical and experimental neuropsychology, 35(*4), 404-412.

Byrne, B. M., Oakland, T., Leong, F. T., van de Vijver, F. J., Hambleton, R. K., Cheung, F. M., & Bartram, D. (2009). A critical analysis of cross-cultural research and testing practices: Implications for improved education and training in psychology. *Training and Education in Professional Psychology*, *3*(2), 94.

Cadavid-Ruiz, N., del Río, P., Egido, J., & Gallindo, P. (2016). Age related changes in the executive function of Colombian children. *Universitas Psychologica, 15*(5). doi:10.11144/Javeriana.upsy15-5.arce

Cagigas, X. E., & Manly, J. J. (2014). Cultural neuropsychology: The new norm. In M. W. Parsons & T. A. Hammeke (Eds.), *Clinical Neuropsychology: A pocket handbook for assessment, Third Edition* (pp. 132-156). Washington, DC: American Psychological Association.

Canivez, G. L., & Kush, J. C. (2013). WAIS-IV and WISC-IV structural validity: Alternative methods, alternate results. Commentary on Weiss et al. (2013a) and Weiss et al. (2013b). *Journal of Psychoeducational Assessment, 31,* 157–169. doi:10.1177/0734282913478036

Canivez, G. L., & Watkins, M. W. (2010a). Exploratory and higher-order factor analyses of the Wechsler Adult Intelligence Scale-(WAIS-IV) adolescent subsample. *School Psychology Quarterly*, *25*(4), 223.

Canivez, G. L., & Watkins, M. W. (2010b). Investigation of the factor structure of the Wechsler Adult Intelligence Scale—Fourth Edition (WAIS–IV): Exploratory and higher order factor analyses. *Psychological Assessment*, *22*(4), 827.

Canivez, G. L., Dombrowski, S. C., & Watkins, M. W. (2018). Factor structure of the WISC-V in four standardization age groups: Exploratory and hierarchical factor analyses with the 16 primary and secondary subtests. *Psychology in the Schools, 55,* 741-769. doi:10.1002/pits.22138

Carroll, J. B. (1993). *Human cognitive abilities: A survey of factor-analytic studies*. New York, NY: Cambridge University Press.

Cavé, J. (2008). *The effect of quality of education on neuropsychological test performance* (Unpublished doctoral dissertation). University of South Africa, Pretoria, South Africa.

Chen, H., & Hua, M.-S. (2019). Selecting tetradic short forms of the Waiwan Wechsler Adult Intelligence Scale IV. *Assessment*, *online first.* doi:10.1177/1073191119831787

Christensen, B. K., Girard, T. A., & Bagby, R. M. (2007). Wechsler Adult Intelligence Scale-Third Edition short form for index and IQ scores in a psychiatric population. *Psychological Assessment, 19*(2), 236-240.

Clara, I. (2000). A psychometric assessment of Wechsler short forms and the Shipley Institute of Living Scale in the estimation of Wechsler Adult Intelligence Scale-III IQ scores with an aging sample (Unpublished master's thesis). University of Manitoba, Manitoba, Winnipeg.

Clauss-Ehlers, C. S., Chiriboga, D. A., Hunter, S. J., & Roysircar, G. (2019). APA Multicultural guidelines: An ecological approach to context, identity, and intersectionality. *American Psychologist, 74*(2), 232-244. doi:10.1037/amp0000382

Cohen, J. (1988). *Statistical power analysis for the behavioural sciences* (2nd ed.). New York: Academic press.

Cores, E. V., Vanotti, S., Eizaguirre, B., Fiorentini, L., Garcea, O., Benedict, R. H., & Cáceres, F. (2015). The effect of culture on two information-processing speed tests. *Applied Neuropsychology: Adult*, *22*(4), 241-245. doi:10.1080/23279090.2014.910214

Crawford, J. R., & Howell, D. C. (1998). Regression equations in clinical neuropsychology: An evaluation of statistical methods for comparing predicted and obtained scores. *Journal of Clinical and Experimental Neuropsychology, 20(*5), 755-762

Crawford, J. R., Allum, S., & Kinion, J. E. (2008). An index-based short form of the WAIS-III with accompanying analysis of reliability and abnormality of differences. *British Journal of Clinical Psychology, 47*, 215-237. doi:10.1348/0I4466507X258859

Cucina, J., & Byle, K. (2017). The bifactor model fits better than the higher-order model in more than 90% of comparisons for mental abilities test batteries. *Journal of Intelligence, 5*(3), 27.

Dana, R. H. (2005). *Multicultural assessment: Principles, applications and examples.* Mahwah, NJ:Erlbaum.

DANE: Departamento administrativo nacional de estadística (2007). *Dirección de censos y demografía: Colombia una nación multicultural.* Retrieved [May 2017] from https://www.dane.gov.co/files/censo2005/etnia/sys/colombia_nacion.pdf.

Daugherty, J. C., Puente, A. E., Fasfous, A. F., Hidalgo-Ruzzante, N., & Pérez-Garcia, M. (2017). Diagnostic mistakes of culturally diverse individuals when using North American neuropsychological tests. *Applied Neuropsychology: Adult*, *24*(1), 16-22. doi:10.1080/23279095.2015.1046992

Denney, D. A., Ringe, W. K., & Lacritz, L. H. (2015). Dyadic Short Forms of the Wechsler Adult Intelligence Scale-IV. *Archives of Clinical Neuropsychology, 30,* 404-412. doi:10.1093/arclin/acv035

Dombrowski, S. C., Canivez, G. L., & Watkins, M. W. (2018). Factor structure of the 10 WISC-V primary subtests across four standardization age groups. *Contemporary School Psychology, 22*(1), 90-104. doi:10.1007/s40688-017-0125-2

Dombrowski, S. C., Canivez, G. L., Watkins, M. W., & Beaujean, A. A. (2015). Exploratory bifactor analysis of the Wechsler Intelligence Scale for Children—Fifth Edition with the 16 primary and secondary subtests. *Intelligence, 53,* 194-201. doi:10.1016/j.intell.2015.10.009

Dombrowski, S. C., McGill, R. J., & Canivez, G. L. (2017). Exploratory and hierarchical factor analysis of the WJ-IV cognitive at school age. *Psychological Assessment, 29*(4), 394-407. doi:10.1037/pas0000350

Dombrowski, S. C., McGill, R. J., & Canivez, G. L. (2018a). An alternative conceptualization of the theoretical structure of the Woodcock-Johnson IV Tests of Cognitive Abilities at school age: A confirmatory factor analytic investigation. *Archives of Scientific Psychology, 6*(1), 1-13. doi:10.1037/arc0000039

Dombrowski, S. C., McGill, R. J., & Canivez, G. L. (2018b). Hierarchical exploratory factor analyses of the Woodcock-Johnson IV full test battery: Implications for CHC application in school psychology. *School Psychology Quarterly, 33*(2), 235-250. doi:10.1037/spq0000221

Donders, J., & Axelrod, B. N. (2002). Two-subtest estimates of WAIS-III factor index scores. *Psychological Assessment, 14,* 260-264. doi:10.1037/1040-3590.14.3.360

Donders, J., Tulsky, D. S., & Zhu, J. (2001). Criterion validity of new WAIS-III subtest scores after traumatic brain injury. *Journal of the International Neuropsychological Society, 7,* 892–898.

Donnell, A. J., Pliskin, N., Holdnack, J., Axelrod, B., & Randolph, C. (2007). Rapidly-administered short forms of the Wechsler Adult Intelligence Scale–3rd edition. *Archives of Clinical Neuropsychology*, *22*, 917-924. doi:10.1016/j.acn.2007.06.007

Drozdick, L. W., Holdnack, J. A., Salthouse, T., & Cullum, C. M. (2013). Assessing cognition in older adults with the WAIS-IV, WMS-IV, and ACS. In J. A. Holdnak, L. W. Drozdick, L. G. Weiss, & G. L. Iverson (Eds.), *WAIS-IV, WMS-IV, and ACS: Advanced clinical interpretation* (pp. 407–483). Boston, MA: Elsevier.

Duggan, E. C., & Garcia-Barrera, M. A. (2015). Executive functioning and intelligence. In S. Goldstein, J. A. Naglieri, & D. Princiotta (Eds.), *Handbook of intelligence: Evolutionary theory, historical perspective, and current concepts* (pp. 435-458). New York: Springer. doi:10.1007/978-1-4939-1562-0_27

Duggan, E. C., & Garcia-Barrera, M. A. (2019). Examining Bifactor and Hierarchical Intelligence Factor Structures in the Chilean adaptation of the WAIS-IV. *In preparation.*

Duggan, E. C., Awakon, L. M., Loaiza, C. C., & Garcia-Barrera, M. A. (2018). Contributing towards a cultural neuropsychology assessment decision-making framework: Comparison of WAIS-IV norms from Colombia, Chile, Mexico, Spain, United States, and Canada. *Archives of Clinical Neuropsychology, online first.* doi:10.1093/arclin/acy074

Dutton, E., & Lynn, R. (2014). The Canadian IQ calculated from the standardization of the WAIS IV. *Open Differential Psychology,* August 20, 2014.

Echemendia, R. J., & Harris, J.G. (2004). Neuropsychological test use with Hispanic/Latino populations in the United States: Part II of a national survey. *Applied Neuropsychology, 11,* 4–11.

Echemendia, R., Harris, J. G., Congett, S., Diaz, M. L., & Puente, A. E. (1997). Neuropsychological training and practices with Hispanics: A national survey. *The Clinical Neuropsychologist, 11*, 29–243.

Edwards, L. M., Burkard, A. W., Adams, H. A., & Newcomb, S. A. (2017). A mixed-method study of psychologists' use of multicultural assessment. *Professional Psychology: Research and Practice*, *48*(2), 131-138. doi:10.1037/pro0000095

Eisman, E. J., Dies, R. R., Finn, S. E., Eyde, L. D., Kay, G. G., Kubiszyn, T. W., … & Moreland, K. L. (2000). Problems and limitations in using psychological assessment in the contemporary health care delivery system. *Professional Psychology: Research and Practice, 31*(2), 131-140. doi:10.1037/0735-7028.31.2.131

Elbulok-Charcape, M. M., Rabin, L. A., Spadaccini, A. T., & Barr, W. B. (2014). Trends in the neuropsychological assessment of ethnic/racial minorities: A survey of clinical neuropsychologists in the United States and Canada. *Cultural Diversity and Ethnic Minority Psychology, 2*0(3), 353.

Fenollar-Cortés, J., & Watkins, M. W. (2018). Construct validity of the Spanish Version of the Wechsler Intelligence Scale for Children Fifth Edition (WISC-V^{Spain}). *International Journal of School & Educational Psychology,* 1-15. doi:10.1080/21683603.2017.1414006

Fernandez, A. L. (2019). Modern neuropsychological tests for a diversity of cultural contexts. *The Clinical Neuropsychologist, online first*. doi:10.1080/13854046.2018.1560501

Fernandez, A. L., Ferreres, A., Morlett-Paredes, A., Rivera, D., & Arango-Lasprilla, J. C. (2016). Past, present, and future of neuropsychology in Argentina. *The Clinical Neuropsychologist, 30*(8), 1154-1178.

Flanagan, D. P., & Harrison, P. L. (Eds.). (2012). *Contemporary intellectual assessment: Theories, tests, and issues* (3rd ed.). New York, NY: The Guildford Press.

Flanagan, D. P., McGrew, K. S., & Ortiz, S. O. (2000). *The Wechsler Intelligence Scales and Gf-Gc theory: A contemporary approach to interpretation*. Boston, MA: Allyn & Bacon.

Flores, I., Casaletto, K. B., Marquine, M. J., Umlauf, A., Moore, D. J., Mungas, D., ... & Heaton, R. K. (2017). Performance of Hispanics and Non-Hispanic Whites on the NIH Toolbox Cognition Battery: The roles of ethnicity and language backgrounds. *The Clinical Neuropsychologist*, *31*(4), 783-797. doi:10.1080/13854046.2016.1276216

Floyd, R. G., Bergeron, R., Hamilton, G., & Parra, G. R. (2010). How do executive functions fit with the Cattell–Horn–Carroll model? Some evidence from a joint factor analysis of the Delis–Kaplan executive function system and the Woodcock–Johnson III tests of cognitive abilities. *Psychology in the Schools, 47*(7), 721-738. doi:10.1002/pits.20500

Fonseca-Aguilar, P., Olabarrieta-Landa, L., Rivera, D., Aguayo Arelis, A., Ortiz Jiménez, X. A., Rabago Barajas, B. V., ... & Arango-Lasprilla, J. C. (2015). Current state of professional Neuropsychological practice in Mexico. *Psicología desde el Caribe, 32*(3), 344-364.

Frazier, T. W., & Youngstrom, E. A. (2007). Historical increase in the number of factors measured by commercial tests of cognitive ability: Are we overfactoring? *Intelligence, 35,* 169 –182. doi:10.1016/j.intell.2006.07.002

Frisby, C. L., & Beaujean, A. A. (2015). Testing Spearman's hypotheses using a bi-factor model with WAIS-IV/WMS-IV standardization data. *Intelligence, 51,* 79-97. doi:10.1016/j.intell.2015.04.007

Fuentes-Durá, I., Romero-Peris, M., Dasí-Vivó, C., & Ruiz-Ruiz, J. C. (2010). Versión abreviada del WAIS-III para su uso en la evaluación de pacientes don diagnóstico de esquizofrenia. *Psicothema, 22*, 202-207.

Fuica, P., Lira, J., Alvarado, K., Araneda, C., Lillo, G., Miranda, R., ... & Pérez-Salas, C. P. (2014). Habilidades cognitivas, contexto rural y urbano: comparación de perfiles WAIS-IV en jóvenes. *Terapia psicológica, 32*(2), 143-152.

Funes, C. M., Hernandez Rodriguez, J., & Lopez, S. R. (2016). Norm comparisons of the Spanish-language and English-language WAIS-III: Implications for clinical assessment and test adaptation. *Psychological Assessment, 28*(12), 1709.

Gasquoine, P. G. (2009). Race-norming of neuropsychological tests. *Neuropsychology Review*, *19*(2), 250-262. doi:10.1007/s11065-009-9090-5

Gignac, G. E. (2008). Higher-order models versus direct hierarchical models: g as superordinate or breadth factor? *Psychology Science Quarterly, 50*(1), 21.

Gignac, G. E. (2014). Fluid intelligence shares closer to 60% of its variance with working memory capacity and is a better indicator of general intelligence. *Intelligence, 47,* 122-133. doi:10.1016/j.intell.2014.09.004

Gignac, G. E. (2016). The higher-order model imposes a proportionality constraint: That is why the bifactor model tends to fit better. *Intelligence, 55,* 57-68. doi:10.1016/j.intell.2016.01.006

Gignac, G. E., & Watkins, M. W. (2013). Bifactor modeling and the estimation of model-based reliability in the WAIS-IV. *Multivariate Behavioral Research, 48*(5), 639-662. doi:10.1080/00273171.804398

Girard, T. A., & Christensen, B. K. (2008). Clarifying problems and offering solutions for correlated error when assessing the validity of selected-subtest short forms. *Psychological assessment, 20*(1), 76.

Girard, T. A., Axelrod, B. N., & Wilkins, L. K. (2010). Comparison of WAIS-III short forms for measuring index and full-scale scores. *Assessment, 17*(3), 400-405.

Girard, T. A., Axelrod, B. N., Patel, R., & Crawford, J. R. (2015). Wechsler Adult Intelligence Scale–IV Dyads for Estimating Global Intelligence. *Assessment, 22*(4), 441-448.

Glass, L. A., Bartels, J. M., & Ryan, J. J. (2009). WAIS-III FSIQ and GAI in ability memory discrepancy analysis. *Applied Neuropsychology, 16*, 19-22.

Golay, P., Reverte, I., Rossier, J., Favez, N., & Lecerf, T. (2013). Further insights on the French WISC–IV factor structure through Bayesian structural equation modeling. *Psychological assessment, 25*(2), 496. doi:10.1037/a0030676

Grégoire, J. (2013). Measuring components of intelligence: Mission impossible? *Journal of Psychoeducational Assessment, 31*(2), 138-147. doi:10.117/0734282913478034

Hair, J. F., Black, B., Babin, B., & Anderson, R. E. (2010). *Multivariate data analysis*. Upper Saddle River, NJ: Pretice Hall.

Hambleton, R. K., Merenda, & P. F., Spielberger, C. D. (Eds.). (2005). *Adapting educational and psychological tests for cross-cultural assessment.* Mahwah, New Jersey: Lawrence Erlbaum Associates, Publishers.

Harrison, A. G., Armstrong, I. T., Harrison, L. E., Lange, R. T., & Iverson, G. L. (2014). Comparing Canadian and American normative scores on the Wechsler Adult Intelligence Scale-Fourth Edition. *Archives of Clinical Neuropsychology, 29*, 737-746.

Harrison, A. G., DeLisle, M. M. & Parker, K. C. H. (2008). An investigation of the General Abilities Index in a group of diagnostically mixed patients. *Journal of Psychoeducational Assessment, 26,* 247-259. doi:10.1177/0734282907304032.

Hays, P. A. (2016). *Addressing cultural complexities in practice: Assessment, diagnosis, and therapy* (3rd ed.). Washington, DC: American Psychological Association.

Helms, J. E. (1992). Why is there no study of cultural equivalence in standardized cognitive ability testing? *American Psychologist, 47*(9), 1083-1101. doi:10.1037/0003-066X.47.9.1083

Hoelzle, J. B. (2008). Neuropsychological assessment and the Cattell-Horn-Carroll (CHC) cognitive abilities model (Dissertation), 1192. http://utdr.utoledo.edu/theses-dissertations/1192

Horn, J. L., & Cattell, R. B. (1966). Refinement and test of the theory of fluid and crystallized intelligence. *Journal of Educational Psychology, 57,* 253-270. doi:10.1037/h00223816

Hu, L., & Bentler, P. M. (1999). Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives. *Structural Equation Modeling, 6,* 1-55. doi:10.1080/10705519909540118

IBM Corp. (Released 2017). IBM SPSS Statistics for Mac, Version 25.0. Armonk, NY: IBM Corp.

INEGI: Instituto Nacional de Estadística y Geografía (2010). *Censo de problación y vivienda 2010.* Retrieved [May 2017] from: http://www.beta.inegi.org.mx/proyectos/ccpv/2010/.

Instituto Cervantes (2016). *El Español: Una lengua viva – Informe 2016. Departmento de Comunicacion Digital del Instituto Cervantes*. Reterived [May 2017] from: www.cervantes.es/imagenes/File/prensa/EspanolLenguaViva16.pdf.

Iverson, G. L., Holdnack, J. A., & Lange, R. T. (2013). Using the WAIS–IV/WMS–IV/ACS Following Moderate-Severe Traumatic Brain Injury. In *WAIS-IV, WMS-IV, and ACS* (pp. 485-544).

Iverson, G. L., Lange, R. T., & Viljoen, H. (2006). Comparing the Canadian and American WAIS-III normative systems in inpatient neuropsychiatry and forensic psychiatry. *Canadian Journal of Behavioral Science, 38,* 4, 348-353.

Jackson, D. L., Gillaspy, J. A., & Purc-Stephenson, R. (2009). Reporting practices in confirmatory factor analysis: An overview and some recommendations. *Psychological Methods, 14,* 6-23. doi:10.1037/a0014694

Jensen, A. (1998). *The g factor: The science of mental ability*. Westport, CT: Praeger.

Jewsbury, P. A., Bowden, S. C. & Duff, K. (2016). The Cattell-Horn-Carroll model of cognition for clinical assessment. *Journal of Psychoeducational Assessment, 35*(6),547-567. doi:10.1177/0734282916651360

Jewsbury, P. A., Bowden, S. C., & Strauss, M. E. (2015). Integrating the switching, inhibition, and updating model of executive function with the Cattell-Horn-Carroll model. *Journal of Experimental Psychology: General, 145*(2), 220-245. doi:10.1037/xge0000119

Jeyakumar, S. L. E., Warriner, E. M., Raval, V. V., & Ahmad, S. A. (2004). Balancing the need for reliability and time efficiency: Short forms of the Wechsler Adult Intelligence Scale-III. *Educational and Psychological Measurement, 64*, 71-87.

Judd, T., Capetillo, D., Carrión-Baralt, J., Mármol, L. M., San Miguel-Montes, L., Navarrete, M. G., ... & the NAN Policy and Planning Committee. (2009). Professional considerations for improving the neuropsychological evaluation of Hispanics: A National Academy of Neuropsychology education paper. *Archives of Clinical Neuropsychology, 24*(2), 127-135.

Kan, K. J., Kievit, R. A., Dolan, C., & van der Maas, H. (2011). On the interpretation of the CHC factor Gc. *Intelligence, 39*(5), 292-302. doi:10.1016/j.intell.2011.05.003

Karr, J. E., Areshenkoff, C. N., Rast, P., Hofer, S. M., Iverson, G. L., & Garcia-Barrera, M. A. (2018). The unity and diversity of executive functions: A systematic review and re-analysis of latent variable studies. *Psychological bulletin*, *144*(11), 1147.

Kaufman, A. S., & Kaufman, N. L. (2004). *Kaufman Brief Intelligence Test, Second Edition (KBIT-2).* San Antonio, TX: Pearson.

Kaufman, A. S., Ishikuma, T., & Kaufman-Packer, J. L. (1991). Amazingly short forms of the WAIS-R. *Journal of Psychoeducational Assessment, 9*, 4-15.

Kaufman, A. S., Johnson, C. K., & Liu, X. (2008). A CHC theory-based analysis of age differences on cognitive abilities and academic skills at ages 22 to 90 years. *Journal of Psychoeducational Assessment, 26*(4), 350-381. doi:10.1177/0734282908314108

Kaufman, J. C., & Kaufman, A. S. (2001). Time for the changing of the guard: A farewell to short forms of intelligence tests. *Journal of Psychoeducational Assessment, 19,* 245-267.

Keith, T. Z., & Reynolds, M. R. (2010). Cattell–Horn–Carroll abilities and cognitive tests: What we've learned from 20 years of research. *Psychology in the Schools, 47*(7), 635-650. doi:10.1002/pits.20496

Keith, T. Z., & Reynolds, M. R. (2018). Using confirmatory factor analysis to aid in understanding the constructs measured by intelligence tests. In D. P. Flanagan & E. M. McDonough (Eds.), *Contemporary intellectual assessment: Theories, tests, and issues* (5th ed., pp. 853-900). New York, NY: The Guilford Press.

Keith, T. Z., Fine, J., Taub, G., Reynolds, M., & Kranzler, J. (2006). Higher order, multi-sample, confirmatory factor analysis of the Wechsler Intelligence Scale for Children–Fourth Edition: What does it measure? *School Psychology Review, 35,* 108-127.

Lange, M., Riveros, R., Figueroa, P., Benavente, C., Aparicio, A. y Rosas, R. (2012). *FIX: Propuesta de nueva herramienta de evaluación de Inteligencia Fluida en adultos*. Centro de Desarrollo de Tecnologías de Inclusión, CEDETi UC, Escuela de Psicología, Pontificia Universidad Católica de Chile.

Lange, R. T., & Chelune, G. J. (2006*).* Application of new WAIS-III/WMS-III discrepancy scores for evaluating memory functioning: Relationship between intellectual and memory ability. *Journal of Clinical and Experimental Neuropsychology, 28*, 592-604.

LaRosa, M. J., & Mejía, G. R. (2017). *Colombia: A concise contemporary history—Second edition.* Lanham, MD: Rowman & Littlefield.

LaRue, A., Romano, L. J., Ortiz, I. E., Liang, H. C., and Lindeman, R. D. (1999). Neuropsychological performance of Hispanic and non-Hispanic older adults: An epidemiologic survey. *Clinical Neuropsychologist, 13,* 474–486.

Lecerf, T., & Canivez, G. L. (2017). Complementary Exploratory and confirmatory factor analyses of the French WISC-V: Analyses based on the standardization sample. *Psychological Assessment, 30*(6), 793-808. doi:10.1037/pas0000526

Lecerf, T., Golay, P., & Reverte, I. (2012) CHC composite scores for the WAIS-IV: French Norms. *Pratiques psychologiques*, *18*(4), 401-412. doi:10.1016/j.prps.201.03.001

Lecerf, T., Golay, P., Reverte, I., Senn, D., Favez, N., & Rossier, J. (2012). CHC composite scores for the WISC-IV: French norms. *Pratiques psychologiques*, *18*(1), 37-50. doi:10.1016/j.prps.2011.04.001

LeGrand, C. C. (2003). The Colombian crisis in historical perspective. *Canadian Journal of Latin American and Caribbean Studies, 28*(55-56), 165-209. doi:10.1080/08263663.2003.10816840

Levy, P. (1967). The correction for spurious correlation in the evaluation of short form tests. *Journal of Clinical Psychology, 23*, 84-86.

Levy, P. (1968). Short form tests: a methodological review. *Psychological Bulletin, 69,* 410-416.

Lezak, M. D., Howieson, D. B., Bigler, E. D., & Tranel, D. (2012). *Neuropsychological assessment* (5th ed.). New York, NY: Oxford University Press.

Llorente, A. M. (Ed.). (2007). *Principles of neuropsychological assessment with Hispanics: Theoretical foundations and clinical practice.* New York, NY: Springer Science & Business Media.

Llorente, A. M., Pontón, M. O., Taussig, I. M., and Satz, P. (1999). Patterns of American immigration and their influence on the acquisition of neuropsychological norms for Hispanics. *Archives of Clinical Neuropsychology, 14,* 603–614.

Lynn, R., Fuerst, J., & Kirkegaard, E. O. W. (2018) Regional differences in intelligence in 22 countries and their economic, social and demographic correlates: A review. *Intelligence, 69,* 24-36. doi:10.1016/j.intell.2018.04.004

Maldonado, C. Y, & Geisinger, K. F. (2005). Conversion of the Wechsler Adult Intelligence Scale into Spanish: An early test adaptation effort of considerable consequence. In R. K. Hambleton, P. F.

Merenda, & C. D. Spielberger (Eds.) Adapting educational and psychological tests for cross-cultural assessment (pp. 213-234). Mahwah, New Jersey: Lawrence Erlbaum Associates, Publishers.

Mansolf, M., & Reise, S. P. (2017). When and why the second-order and bifactor models are distinguishable. *Intelligence, 61,* 120-129. doi:10.1016/j.intell.2017.01.012

Many, J. J. (2008). Critical issues in cultural neuropsychology: Profit from diversity. *Neuropsychological Review, 18*(3), 179-183.

Marsella, A. J. (1998). Toward a “global-community psychology”: Meeting the needs of a changing world. *American Psychologist, 53*, 1282-1291. doi:10.1037/0003-066X.53.12.1282

Marsh, H. W., Balla, J. R., & McDonald, R. P. (1988). Goodness-of-fit indexes in confirmatory factor analysis: The effect of sample size. *Psychological Bulletin, 103,* 391-410. doi:10.1037/0033-2909.103.391

McDonald, R. P. (1999). *Test theory: A unified approach.* Mahwah, NJ: Erlbaum.

McPherson, S., Buckwalter, G. J., Tingus, K., Betz, B., & Back, C. (2000). The Satz-Mogel Short Form of the Wechsler Adult Intelligence Scale Revised: Effects of Global Mental Status and Age on Test-Retest Reliability. *Journal of Clinical and Experimental Neuropsychology, 22*(5), 545-553.

Mendella, P. D., McFadden, L., Regan, J., & Medlock, L. (2000). Short form prediction of WAIS-R scores in a sample of individuals diagnosed with multiple sclerosis. *Applied neuropsychology*, *7*(2), 102-107.

Meyers, J. E., Zellinger, M. M., Kockler, T., Wagner, M., & Miller, R. M. (2013). A validated seven-subtest short form for the WAIS-IV. *Applied Neuropsychology: Adult, 20*(4), 249-256.

Miller, H. R., Steiner, D. L., & Goldberg, J. O. (1996). Short, shorter, shortest: The efficacy of WAIS-R short forms with mixed psychiatric patients. *Assessment, 3*, 1651-69.

Miyake, A., & Friedman, N. P. (2012). The nature and organization of individual differences in executive functions four general conclusions. *Current Directions in Psychological Science, 21*(1), 8-14. doi:10.1177/0963721411429458

Morgan-Consoli, M. L., Inman, A. G., Bullock, M., & Nolan, S. A. (2018). Framework for competencies for U.S. psychologists engaging internationally. *International Perspectives in Psychology: Research, Practice, Consultation, 7*(3), 174-188. doi:10.1037/ipp0000090

Murray, A. L., & Johnson, W. (2013). The limitations of model fit in comparing the bi-factor versus higher-order models of human cognitive ability structure. *Intelligence, 41*(5), 407-422. doi:10.1016/j.intell.2013.06.004

Muthén, L. K., & Muthén, B. O. (1998-2017). *Mplus User's Guide. Eighth Edition.* Los Angeles, CA: Muthén & Muthén.

Niileksela, C. R., Reynolds, M. R., & Kaufman, A. S. (2013). An alternative Cattell–Horn–Carroll (CHC) factor structure of the WAIS-IV: Age invariance of an alternative model for ages 70–90. *Psychological Assessment, 25*(2), 391. doi:10.1037/a0031175

O'Bryant, S. E., Edwards, M., Johnson, L., Hall, J., Gamboa, A., & O'jile, J. (2018). Texas Mexican American adult normative studies: Normative data for commonly used clinical neuropsychological measures for English-and Spanish-speakers. *Developmental Neuropsychology*, *43*(1), 1-26. doi:10.1080/87565641.2017.1401628

Olabarrieta-Landa, L., Caracuel, A., Pérez-García, M., Panyavin, I., Morlett-Paredes, A., & Arango-Lasprilla, J. C. (2016). The profession of neuropsychology in Spain: Results of a national survey. *The Clinical Neuropsychologist, 30*(8), 1335-1355.

Olivier, T. W., Golden, C. J., Acevedo, A., Sterk, V. I., Espinosa, K. M., & Spengler, K. M. (2014). WAIS-IV Index and Full Scale Intelligence Quotient Score Differences between Standard and Prorated Scoring Methods. *Archives of Assessment Psychology, 3*(1), 57-77.

Olson, K., & Jacobson, K. (2015). Cross-cultural considerations in pediatric neuropsychology: A review and call to attention. *Applied Neuropsychology: Child*, *4*(3), 166-177. doi:10.1080/21622965.2013.830258

Oosterhuis, H. E., van der Ark, L. A., & Sijtsma, K. (2017). Standard errors and confidence intervals of norm statistics for educational and psychological tests. *Psychometrika,* 1-30.

Ortiz, S. O. (2015). CHC theory of intelligence. In S. Goldstein, D. Princiotta, & J. A. Naglieri (Eds.), *Handbook of Intelligence* (pp. 209-227). New York, NY: Springer. doi:10.1007/978-1-4939-1562-0_15

Pearson Clinical (2019). Clinical Assessment: Content and Translations. Retrieved April 1, 2019 from https://www.pearsonassessments.com/professional-assessments/featured-topics/pharma-licensing/content---translations.html

Pedraza, O., & Mungas, D. (2008). Measurement in cross-cultural neuropsychology. *Neuropsychology Review, 18*(3), 184-193. doi:10.1007/s11065-008-9067-9

Pezzuti, L., Lang, M., Rossetti, S., & Michelotti, C. (2018). CHC Model According to Weiss. *Journal of Individual Differences, 39*(1), 53-59. doi:10.1027/1614-0001/a000249

Pilgrim, B. M., Meyers, J. E., Bayless, J., & Whetstone, M. M. (1999). Validity of the Ward seven-subtest WAIS-III short form in a neuropsychological population. *Applied Neuropsychology, 6*, 243-246.

Pontón, M. O., & Ardila, A. (1999). The future of neuropsychology with Hispanic populations in the United States. *Archives of Clinical Neuropsychology, 14*(7), 565-580.

Puente, A. E., Perez-Garcia, M., Vilar-Lopez, R., Hidalgo-Ruzzante, N., & Fasfous, A. F. (2013). Neuropsychological assessment of culturally and educationally dissimilar individuals. In F. A. Paniagua & A. Yamada (Eds.) *Handbook of multicultural mental health: Assessment and treatment of diverse populations* (pp. 225-242). San Diego, CA: Academic Press.

Puente, A.E., & Ardila, A. (2000). Neuropsychological assessment of Hispanics. In E. Fletcher-Jonzen, T. Stricklond & C.R. Reynolds (Eds.)., *Handbook of cross-cultural neuropsychology* (pp. 87–104). New York: Kluwer Academic/Plenum Publishers.

Rabin, L. A., Paolillo, E., & Barr, W. B. (2016). Stability in test-usage practices of clinical neuropsychologists in the United States and Canada over a 10-year period: A follow-up survey of INS and NAN members. *Archives of Clinical Neuropsychology, 31,* 206-230. doi:10.1093/arclin/acw007

Rabin, L. A., Paolillo, E., & Barr, W. B. (2016). Stability in test-usage practices of clinical neuropsychologists in the United States and Canada over a 10-year period: A follow-up survey of INS and NAN members. *Archives of Clinical Neuropsychology, 31,* 206-230. doi:10.1093/arclin/acw007

Ready, R. E., & Barnett Veague, H. (2014). Training in psychological assessment: Current practices of clinical psychology programs. *Professional Psychology: Research and Practice*, *45*(4), 278.

Reid-Arndt, S. A., Allen, B. J., & Schopp, L. (2011). Validation of WAIS-III four-subtest short forms in patients with traumatic brain injury. *Applied Neuropsychology, 18,* 291-297. doi:10.1080/09084282.2011.595456

Reise, S. P. (2012). The rediscovery of bifactor measurement models. *Multivariate Behavioral Research, 47*, 667-696. doi:10.1080/00273171.2012.715555

Reise, S. P., Bonifay, W. E., & Haviland, M. G. (2013). Scoring and modeling psychological measures in the presence of multidimensionality. *Journal of Personality Assessment, 95*, 129-140. doi:10.1080/00223891.

Reise, S. P., Scheines, R., Widaman, K. F., & Haviland, M. G. (2013). Multidimensionality and structural coefficient bias in structural equation modeling: A bifactor perspective. *Educational and Psychological Measurement, 73*(1), 5-26. doi:10.1177/0013164412449831

Renteria, L., Li, S. T., & Pliskin, N. H. (2008). Reliability and validity of the Spanish Language Wechsler Adult Intelligence Scale in a sample of American, urban, Spanish-speaking Hispanics. *The Clinical Neuropsychologist, 22*(3), 455-470.

Reverte, I., Golay, P., Favez, N., Rossier, J., & Lecerf, T. (2015). Testing for multigroup invariance of the WISC-IV structure across France and Switzerland: Standard and CHC models. *Learning and Individual Differences, 40,* 127-133. doi:10.1016/j.lindif.2015.03.015

Ridley, C. R., Tracy, M. L., Pruitt-Stephens, L., Wimsatt, M. K., & Beard, J. (2008). Multicultural assessment validity: The preeminent ethical issue in psychological assessment. In L. A. Suzuki & J. G. Ponterotto (Eds.), *Handbook of multicultural assessment: Clinical, psychological and educational applications* (3rd ed., pp. 22–33). San Francisco, CA: Wiley.

Ringe, W. K., Saine, K. C., Lacritz, L. H., Hynan, L. S., & Cullum, C. M. (2002). Dyadic short forms of the Wechsler Adults Intelligence Scale-III. *Assessment, 9*, 254-260.

Rivera Mindt, M. Arentoft, A., Coulehan, K., Summers, A. C., Tureson, K., Aghvinian, M., & Byrd, D. A. (2019). Neuropsychological evaluation of culturally/linguistically diverse older adults. In L. D. Ravdin & H. L. Katzen (Eds.), Handbook on the Neuropsychology of Aging and Dementia (2nd ed.). Switzerland: Springer Nature.

Rivera Mindt, M., Byrd, D., Saez, P., & Manly, J. (2010). Increasing culturally competent neuropsychological services for ethnic minority populations: A call to action. *The Clinical Neuropsychologist, 24*(3), 429-453.

Rodriquez, A. Reis, S. P. & Haviland, M. G. (2016). Evaluating bifactor models: Calculating and interpreting statistical indices. *Psychological Methods, 21*(2), 137-150. doi:10.1037/met00000045

Rosas, R., Tenorio, M., Pizarro, M., Cumsille, P., Bosch, A., Arancibia, S., ... & Zapata-Sepúlveda, P. (2014). Estandarización de la Escala Wechsler de Inteligencia para Adultos: cuarta edición en Chile. *Psykhe (Santiago)*, *23*(1), 1-18.

Rosselli, M., & Ardila, A. (2003). The impact of culture and education on non-verbal neuropsychological measurements: A critical review. *Brain and cognition*, *52*(3), 326-333. doi:10.1016/S0278-2626(03)00170-2

Ryan, J. J., & Ward, L. C. (1999). Validity, reliability, and standard errors of measurement for two seven-subtest short forms of the Wechsler Intelligence Scale-III. *Psychological Assessment, 11*(2), 207-211. doi:10.1037/1040-3590.11.2.207

Ryan, J. J., Kreiner, D. S., Gontkovsky, S. T., & Glass Umfleet, L. (2015). Classification accuracy of sequentially administered WAIS-IV short forms. Applied Neuropsychology: Adult, 22(6), 409-414.

Ryan, J. J., Lopez, S. J., & Werth, T. R. (1998). Administration time estimates for WAIS-III subtests, scales, and short forms in a clinical sample. *Journal of Psychoeducational Assessment, 16(4),* 315-323.

Sanchez, L. M., & Turner, S. M. (2003). Practicing psychology in the era of managed care: Implications for practice and training. *American Psychologist, 58*(2), 116-129. doi:10.1037/0003-066X.58.2.116

Santamaría, P., & Fernández Pinto, I. (2009). *RIAS Escalas de Inteligencia de Reynolds y RIST Test de Inteligencia Breve de Reynolds Manual.* Adaptación española. Madrid, Spain: TEA Ediciones.

Santamaría, P., Arribas, D., Pereña, J., & Seisdedos, N. (2005). *Evaluación Factorial de las Aptitudes Intelectuales (EFAI).* Adaptación española. Madrid, Spain: TEA Ediciones.

Satterfield, W. A., Martin, C. W., & Leiker, M. (1994). A comparison of four WAIS-R short forms in patients referred for psychological/neuropsychological assessments. *Journal of Psychoeducational Assessment, 12,* 364-371.

Sattler, J. M., & Ryan, J. J. (2009). *Assessment with the WAIS-IV.* San Antonio, TX: Psychological Corporation.

Schermelleh-Engel, K., Moosbrugger, H., & Müller, H. (2003). Evaluating the fit of structural equation models: Tests of significance and descriptive goodness-of-fit measures. *Methods of Psychological Research Online, 8,* 23-74.

Schmid, J., & Leiman, J. M. (1957). The development of hierarchical factor solutions. *Psychometrika, 22*(1), 53-61. doi:10.1007/BF02289209

Schneider, W. J., & Flanagan, D. P. (2015). The relationship between theories of intelligence and intelligence tests. In S. Goldstein, D. Princiotta, & J. A. Naglieri (Eds.), *Handbook of intelligence* (pp. 317-340). New York, NY: Springer.

Schneider, W. J., & McGrew, K. S. (2018). The Cattell-Horn-Carroll theory of cognitive abilities. In D. P. Flanagan & E. M. McDonough (Eds.), *Contemporary intellectual assessment: Theories, tests, and issues* (5th ed., pp. 73-163). New York, NY: The Guilford Press.

Schoenberg, M. R., Duff, K., Dorfman, K., & Adams, R. L. (2004). Differential estimation of verbal intelligence and performance intelligence scores from combined performance and demographic variables: The OPIE-3 verbal and performance algorithms. *Clinical Neuropsychology, 16*, 266-276. doi:10.1080/13854040490501501

Schrank, F. A., McGrew, K. S., & Mather, N. (2014). *Woodcock-Johnson IV Tests of Cognitive Abilities.* Rolling Meadows, IL: Riverside.

Schreiber, J. B., Nora, A., Stage, F. K., Barlow, E. A., & King, K. (2006). Reporting structural equation modeling and confirmatory factor analysis results: A review. *Journal of Educational Research, 99*, 323-338. doi:10.3200/JOER.99.6.323-338

Shuttleworth-Edwards, A. B. (2016). Generally representative is representative of none: Commentary on the pitfalls of IQ test standardization in multicultural settings. *The Clinical Neuropsychologist, 30*(7), 975-998.

Shuttleworth-Edwards, A. B. (2017). Countrywide norms declared obsolete: Best practice alert for IQ testing in a multicultural context. *South African Journal of Psychology, 41*(1), 3-6.

Shuttleworth-Edwards, A. B., Gaylard, E. K., & Radloff, S. E. (2013). WAIS-III test performance in the South African context: Refinement of an existing cross-cultural normative database. In K. Cockcroft & S. Laher (Eds.), *Psychological assessment in South Africa: Research and applications* (pp. 17-32). Johannesburg: Wits Press.

Shuttleworth-Edwards, A. B., Kemp, R. D., Rust, A. L., Muirhead, J. G., Hartman, N. P., & Radloff, S. E. (2004). Cross-cultural effects on IQ test performance: A review and preliminary normative indications on WAIS-III test performance. *Journal of Clinical and Experimental Neuropsychology, 26*(7), 903-920.

Silverstein, A. B. (1982). Two- and four-subtest short forms of the Wechsler Adult Intelligence Scale-Revised. *Journal of Consulting and Clinical Psychology, 50,* 415-418. doi:10.1037/0022-006X.50.3.415

Silverstein, A. B. (1985). An appraisal of three criteria for evaluating the usefulness of WAIS-R short forms. *Journal of Clinical Psychology, 41*, 676-680.

Silverstein, A. B. (1990). Short forms of individual intelligence tests. *Psychological Assessment: A Journal of Consulting and Clinical Psychology, 2*(1), 3.

Smith, G. T., McCarthy, D. M., & Anderson, K. G. (2000). On the sins of short form development. Psychological assessment, 12(1), 102.

Spearman, C. (1904). “General intelligence,” objectively determined and measured. *American Journal of Psychology, 15*, 201-293. doi:10.2307/1412107

Staffaroni, A. M., Eng, M. E., Moses Jr, J. A., Zeiner, H. K., & Wickham, R. E. (2018). Four-and five-factor models of the WAIS-IV in a clinical sample: Variations in indicator configuration and factor correlational structure. *Psychological Assessment, 5*, 693-706. doi:10.1037/pas0000518

Suchy, Y. (2016). Population-based norms in crisis. *Clinical Neuropsychologist, 30,* 973-974.

Sunderaraman, P., Zahodne, L. B., & Manly, J. J. (2016). A commentary on 'generally representative is representative of none: Pitfalls of IQ test standardization in multicultural settings' by AB Shuttleworth-Edwards. *The Clinical Neuropsychologist, 30*(7), 999-1005.

Suzuki, L. A., & Ponterotto, J. G. (Eds.). (2008). *Handbook of multicultural assessment: Clinical, psychological, and educational applications* (3rd ed.). San Francisco, CA: John Wiley & Sons, Inc.

Taylor, N. (2016). Generally representative is generally representative: Comment on Shuttleworth-Edwards. *The Clinical Neuropsychologist, 30*(7), 1017-1022.

Tellegen, A., & Briggs, P. F. (1967). Old wine in new skins: grouping Wechsler subtests into new scales. *Journal of consulting psychology, 31*(5), 499.

Thaler, N. S., & Jones-Forrester, S. (2013). IQ testing and the Hispanic client. In L. T. Benuto (Ed.), *Guide to psychological assessment with Hispanics* (pp. 81-98). New York, NY: Springer.

Thompson, A. P., LoBello, S. G., Atkinson, L., Chisholm, V., & Ryan, J. J. (2004). Brief intelligence testing in Australia, Canada, the United Kingdom, and the United States. *Professional Psychology: Research and Practice, 35,* 286-290. doi:10.1037/0735-7028.35.3.286

Úbeda, R., Fuentes, I., & Dasí, C. (2016). Revisión de las formas abreviadas de la Escala de Inteligencia de Wechsler para Adultos.

UNESCO Institute for Statistics (2012). *International Standard Classification of Education: ISCED 2011.* Montreal: UNESCO Institute for Statistics.

UNESCO Institute for Statistics (2017). UNESCO Institute for Statistics: Country data. Retrieved [May 2017] from: http://uis.unesco.org/en/.

Uzzell, B. P., Ponton, M., & Ardila, A. (Eds.). (2007). *International handbook of cross-cultural neuropsychology*. Mahwah, NJ: Lawrence Earlbaum Associates, Publishers.

van Aken, L., Kessels, R. P. C., Wingbermühle, E., Wiltink, M., van der Heijden, P. T., & Egger, J. I. M. (2014) Exploring the incorporation of executive functions in intelligence testing: Factor analysis of the WAIS-III and traditional tasks of executive functioning. *International Journal of Applied Psychology, 4*(2), 73-80. doi:10.5923/j.ijap.20140402.05

van Aken, L., van der Heijden, P. T., van der Veld, W. M., Hermans, L., Kessels, R. P. C., & Egger, J. I. M. (2017). Representation of the Cattell-Horn-Carroll theory of cognitive abilities in the factor structure of the Dutch-language version of the WAIS-IV. *Assessment, 24*(4), 458-466. doi:10.1177/1073191115607973

van Duijvenbode, N., Didden, R., van den Hazel, T., & Engels, R. C. (2016). Psychometric qualities of a tetrad WAIS-III short form for use in individuals with mild to borderline intellectual disability. *Developmental neurorehabilitation, 19*(1), 26-30.

van Ool, J. S., Hurks, P. P., Snoeijen-Schouwenaars, F. M., Tan, I. Y., Schelhaas, H. J., Klinkenberg, S., ... & Hendriksen, J. G. (2017). Accuracy of WISC-III and WAIS-IV short forms in patients with neurological disorders. *Developmental Neurorehabilitation,* 1-7.

von Thomsen, C., Gallup, L., & Llorente, A. M. (2008). Intellectual abilities: Theoretical and applied assessment considerations. In A. M. Llorente, (Ed.) *Principles of neuropsychological assessment with Hispanics* (pp. 57-77). New York, NY: Springer.

Wagner, F., Pawlowski, J., Yates, D. B., Camey, S. A., & Trentini, C. M. (2010). Viability of IQ estimates based on Vocabulary and Block Design WAIS-III subtests. *Psico-USF, 15(*2), 215-224.

Ward, L. C. (1990). Prediction of verbal, performance, and full scale IQs from seven subtests of the WAIS-R. *Journal of Clinical Psychology, 46*(4), 436-440. doi:10.1002/1097-4679(199007)46:4<436::AID-JCLP2270460411>3.0.CO;2-M

Ward, L. C., Bergman, M. A., & Hebert, K. R. (2012). WAIS-IV subtest covariance structure: Conceptual and statistical considerations. *Psychological Assessment*, *24*(2), 328. doi:10.1037/a0025614

Warne, R. T., & Burningham, C. (2019). Spearman's g Found in 31 Non-Western Nations: Strong Evidence that g is a Universal Phenomenon. *Psychological Bulletin,* 145(3), 237-272. doi:10.31234/osf.io/uv673

Watkins, M. W., Dombrowski, S. C., & Canivez, G. L. (2018). Reliability and factorial validity of the Canadian Wechsler Intelligence Scale for Children-Fifth Edition. *International Journal of School & Educational Psychology, 6*(4), 252-265. doi:10.1080/21683603.2017.1342580

Wechsler, D. (1997). *The Wechsler Adult Intelligence Scale, Third Edition.* San Antonio, TX: The Psychological Corporation.

Wechsler, D. (1999). *WASI (Wechsler Adult Scale-reduced)*. New York: The Psychological Corporation.

Wechsler, D. (2001). *WAIS-III: Escala de Inteligencia Wechsler para Adultos-III.* Madrid, Spain: T.E.A. Ediciones.

Wechsler, D. (2003). *Escala Wechsler de Inteligencia para Adultos-III.* Mexico City, Mexico: Manual Moderno.

Wechsler, D. (2008a). *Escala de Inteligencia Wechsler para Adultos – Tercera Ediction (EIWA-III).* San Antonio, TX: Pearson.

Wechsler, D. (2008b). *Wechsler Adult Intelligence Scale–Fourth Edition.* San Antonio, TX: Pearson.

Wechsler, D. (2008c). *Wechsler Adult Intelligence Scale–Fourth Edition: Technical and interpretive manual.* San Antonio, TX: Pearson.

Wechsler, D. (2008d). *Wechsler Adult Intelligence Scale–Fourth Edition: Canadian (WAIS-IV CDN).* Toronto, Ontario: Pearson Canada.

Wechsler, D. (2008e). *Wechsler Adult Intelligence Scale–Fourth Edition: Canadian Technical Manual.* Toronto, Ontario: Pearson Canada.

Wechsler, D. (2011). *Wechsler Abbreviated Scale of Intelligence—Second Edition (WASI-II).* San Antonio, TX: Pearson.

Wechsler, D. (2012a). *WAIS-IV. Escala de inteligencia de Wechsler para adultos-IV. Manual de aplicación y corrección.* Madrid: NCS Pearson, Inc. Edición original, 2008.

Wechsler, D. (2012b). WAIS-IV. *Escala de inteligencia de Wechsler para adultos-IV. Manual tecnico y de interpretación.* Madrid: NCS Pearson, Inc. Edición original, 2008.

Wechsler, D. (2012c). *Wechsler Preschool and Primary Scale of Intelligence—Fourth Edition (WPPSI-IV).* San Antonio, TX: Pearson.

Wechsler, D. (2013). *WAIS-IV. Escala de inteligencia de Wechsler para adultos-IV. Manual de aplicación y corrección- Versión chilena.* Chile: NCS Pearson, Inc. Edición original, 2008. Traducción castellana, 2012.

Wechsler, D. (2014a). *WAIS-IV. Escala de inteligencia de Wechsler para adultos-IV. Manual de aplicación y corrección- Versión méxicana.* Traducción al español por Editorial El Manual Moderno, S. A. de C. V. D. R. Traducido por M. C. Uribe Ferrari; coordinación de estandarización Facultad de Psicologia, Universidad Nacional Autónoma de México; análisis estadistico J. Zhu, Y. Meng, I. Martinez. J. L. Morales Saavedra & T. Uriza Gómez (Eds.). D. F., México: NCS Pearson, Inc.

Wechsler, D. (2014b). *Wechsler Intelligence Scale for Children—Fifth Edition (WISC-V)*. San Antonio, TX: Pearson.

Wechsler, D. (2016). *Escala de inteligencia de Wechsler para adultos-cuarta edición (WAIS-IV). Manual de administración y corrección, versión estandarizada en Colombia.* Documento escrito para NCS Pearson, Inc. por R. Rosas D., M. Tenorio D., & M. Pizarro M. La versión adaptada y estandarizada para Colombia se ha escrito con apoyo de F. Lopera & S. Moreno. Chile: NCS Pearson, Inc. Edición original, 2008. Traducción castellana, 2012.

Weiss, L. G., Keith, T. Z., Zhu, J., & Chen, H. (2013a). Technical and practical issues in the structure and clinical invariance of the Wechsler Scales: A rejoinder to commentaries. *Journal of Psychoeducational Assessment, 31,* 235-243. doi:10.1177/0734282913478050

Weiss, L. G., Keith, T. Z., Zhu, J., & Chen, H. (2013b). WAIS-IV and clinical validation of the four- and five-factor interpretative approaches. *Journal of Psychoeducational Assessment, 31,* 94-113. doi:10.1177/0734282913478030

Weiss, L. G., Keith, T. Z., Zhu, J., & Chen, H. (*2013c). WISC-IV and clinical validation of the four and five-factor interpretative approaches. Journal of Psychoeducational Assessment, 31,* 114-131. doi:10.1177/0734282913478032

Weiss, L. G., Saklofske, D. H., Coalson, D., & Raiford, S. E. (Eds.). (2010). *WAIS-IV clinical use and interpretation: Scientist-practitioner perspectives*. San Diego, CA: Academic Press.

Whipple Drozdick, L., Wahlstrom, D., Zhu, J., & Weiss, L. G (2012). The Wechsler Adult Intelligence Scale—Fourth Edition and the Wechsler Memory Scale—Fourth Edition. In D. P. Flanagan & P. L. Harrison (Eds.), *Contemporary intellectual assessment: Theories, tests, and issues* (3rd ed., pp. 197-223). New York, NY: The Guilford Press.

Wicherts, J. M. (2016). The importance of measurement invariance in neurocognitive ability testing. *The Clinical Neuropsychologist, 30*(7), 1006-1016.

Woodcock, R. W., Maricle, D. E., Miller, D. C., & McGill, R. J. (2018). Functional Cattell-Horn-Carroll nomenclature for practical applications. In D. P. Flanagan & E. M. McDonough (Eds.), *Contemporary intellectual assessment: Theories, tests, and issues* (5th ed., pp. 901-911). New York, NY: The Guilford Press.

World Bank (2017). *Colombia- Educational Attainment from the Barro-Lee Educational Attainment Dataset (2010).* Retrieved [April 2017] from: http://www.worldbank.org.

World Economic Forum (2017-2018). *The global competitiveness report 2017-2018. Geneva: World Economic Form.* Retrieved [April 2018] from: http://reports.weforum.org/global-competitiveness-index-2017-2018/.

Wright, C. V., Beattie, S. G., Galper, D. I., Church, A. S., Bufka, L. F., Brabender, V. M., & Smith, B. L. (2017). Assessment practices of professional psychologists: Results of a national survey. *Professional Psychology: Research and Practice*, *48*(2), 73.

Wymer, J. H., Rayls, K., & Wagner, M. T. (2003). Utility of a clinically derived abbreviated form of the WAIS-III. *Archives of Clinical neuropsychology, 18*(8), 917-927. doi:10.1016/S0887-6177(02)00221-4

Yang, R., Spirtes, P., Scheines, R., Reise, S. P., & Mansoff, M. (2017). Finding Pure Submodels for Improved Differentiation of Bifactor and Second-Order Models. Structural equation modeling: a multidisciplinary journal, 24(3), 402-413.

Tables

Table 1.1 Demographics for current sample of Colombian executives

Variable	*n* (%)
Total (*N*)	305
Men	158 (51.8%)
Women	147 (48.2%)
Age in years (*M* ± *SD*)	35.24 ± 10.1
16 to 19	0 (0%)
20 to 24	60 (19.67%)
25 to 29	55 (18.03%)
30 to 34	46 (15.08%)
35 to 44	86 (28.20%)
45 to 54	46 (15.08%)
55 to 64	12 (3.93%)
65 to 90	0 (0%)
Education in years (*M* ± *SD*)	17.16 ± 1.43
SES Categorization[1]	
ISCED 0-1: Less than Compulsory Education	0 (0%)
ISCED 2-6: Less than Compulsory to Tertiary/Post-secondary Education	215 (70.49%)
ISCED 7-8: Graduate Education	90 (29.51%)
ISCED Categorization[2]	
ISCED 1-3: Compulsory Education	1 (0.33%)
ISCED 4-6: Tertiary/Post-secondary Education	118 (38.69%)
ISCED 7-8: Graduate Education	186 (60.98%)

[1]Based on the same SES categorization used for the development of the Colombian and Chilean WAIS-IV norms.

[2]Based on the International Standard Classification of Education (ISCED; UNESCO Institute for Statistics; 2012) as used in Tables 3 and 4.

Table 1.2. Demographics of study-relevant countries

	Colombia	Chile	Mexico	Spain	USA	Canada
Total population (in thousands)[1]	48,229	17,948	127,017	46,122	321,774	35,940
Population adult (% ≥ 15 yrs)[1]	76%	80%	72%	85%	81%	84%
World ranking- most Spanish speakers[2]	3	9	1	4	2	25
Total Spanish speakers (estimated %)[2]	99.2%	95.9%	96.8%	92.1%	17.9%	2.00%
Spanish speakers who are native speakers (%)[2]	99%	96%	97%	92%	74%	58%
Rural population (%)[1]	24%	10%	21%	20%	18%	18%
Literacy rate (%)[1]	95%	97%	95%	98%	--	--
Average education attainment (yrs)[3]	9.35	10.35	9.18	10.75	13.24	12.74
Quality of education: total score[4, 5]	3.8	4.1	3.5	4.5	5.7	5.6
Quality of education: global ranking[4]	77	62	106	38	5	7
Quantity of education: total score[4, 6]	5.8	7	4.7	7	7	6.3
Quantity of education: global ranking[4]	49	1	78	1	1	28
Composite education indicator: total scores[4, 7]	4.5	5.3	4.1	5.2	6.1	5.8
Composite education indicator: global ranking[4]	66	26	80	28	3	13

[1]UNESCO Institute for Statistics (2017).

[2]Instituto Cervantes (2016).

[3]World Bank (2017).

[4]World Econonimc Forum, (2017-2018). Notes: All scores based on a scale raning from 1 to 7. All global rankings allow for ties.

[5]Total international quality of education based on the World Economic Forum, Executive Opinion Survey; min score = 2.24, max score = 6.13; median = 3.85.

[6]Based on number of years of education completed as defined by the Global Competitiveness Index; min score = 1.00, max score = 7.00; median = 3.17.

[7]Overall higher education and training score combining multiple indicators of quality and quantity of education; min = 1.90, max = 6.27, median = 3.63.

Table 1.3 Educational attainment of the adult population (aged 25 and older) for each country of interest

Country	**Colombia**	**Chile**	**Mexico**	**Spain**	**USA**	**Canada**
Year	2015	2013	2015	2015	2015	2011
Adult population (in thousands)	28,248	11,144	66,677	34,933	216,786	24,243
International Standard Classification of Education (ISCED)[2]						
No Education	7.00%	3.00%	7.70%	2.00%	0.40%	ISCED 2*
Incomplete Primary (ISCED 1)	16.90%	11.20%	13.00%	7.50%	0.80%	ISCED 2*
Primary (ISCED 1)	25.60%	9.40%	19.60%	15.60%	3..4%	ISCED 2*
Lower Secondary (ISCED 2)	4.90%	22.00%	26.10%	27.00%	6.90%	17.30%
Upper Secondary (ISCED 3)	25.80%	35.50%	17.00%	18.60%	46.10%	23.10%
Post-secondary non-tertiary (ISCED 4)	ISCED 5*	ISCED 5*	ISCED 5*	ISCED 3*	ISCED 3*	12.00%
Short-cycle tertiary (ISCED 5)	9.20%	6.00%	1.50%	29.30%	9.80%	ISCED 6*
Bachelor's or equivalent (ISCED 6)	7.10%	11.20%	12.60%	ISCED 5	20.50%	47.70%
Master's or equivalent (ISCED 7)	3.20%	1.00%	1.90%	ISCED 5	10.30%	ISCED 6*
Doctoral or equivalent (ISCED 8)	ISCED 7*	ISCED 7*	0.20%	ISCED 5	1.70%	ISCED 6*
Unknown	0.30%	0.60%	0.40%	--	--	--
Summary of Above						
ISCED 1-3 (Compulsory Education/High school)	80.20%	81.10%	83.40%	70.70%	54.20%	40.40%
ISCED 4-6 (Post-secondary Education/Bachelor's)	16.30% 19.50%	17.20% 18.20%	14.10% 16.20%	29.30%	30.30% 42.30%	59.70%
ISCED 7-8 (Graduate/Master's and Doctoral)	3.20%	1.00%	2.10%		12.00%	

[1]UNESCO Institute for Statistics (2017).

[2]UNESCO Institute for Statistics (2012); *Indicated measurement of this level of education was combined with another level.

Table 1.4. Demographics of the Colombia, Chilean, Mexican, Spanish, American, and Canadian WAIS-IV normative samples[1]

	FSIQ	VCI	PRI	WMI	PSI
Colombia					
Mean (*SD*)	120.30 (8.81)	118.85 (9.85)	117.53 (10.82)	118.29 (11.84)	121.15 (12.00)
Standard Error	0.51	0.56	0.62	0.68	0.69
Chile*					
Mean (*SD*)	120.59 (9.79)	117.90 (10.11)	117.21 (11.21)	118.33 (12.30)	120.48 (12.45)
Standard Error	0.56	0.58	0.64	0.71	0.71
Mean Difference (*SD*)	**0.29 (0.97)**	**-0.95 (0.25)**	**-0.48(0.40)**	0.05 (0.46)	**-0.68 (0.45)**
Difference Effect Size (*r*)	0.237	0.891	0.668	0.066	0.731
% within ± 5 points	99.34%	100.00%	100.00%	100.00%	100.00%
% 3 classifications higher	--	--	--	--	--
% 2 classifications higher	--	--	--	--	--
% 1 classification higher	1.31%	--	--	6.89%	--
% within same classification	97.38%	88.20%	99.67%	85.25%	100.00%
% 1 classification lower	1.31%	11.80%	0.33%	7.87%	--
% 2 classifications lower	--	--	--	--	--
% 3 classifications lower	--	--	--	--	--
% within ± 5 points or same classification	100.00%	100.00%	100.00%	100.00%	100.00%
Mexico*					
Mean (*SD*)	117.61 (10.14)	122.50 (11.95)	112.10 (11.09)	111.06 (12.01)	112.31 (8.96)
Standard Error	0.58	0.68	0.64	0.69	0.51
Mean Difference (*SD*)	**-2.70 (1.32)**	**3.65 (2.10)**	**-5.43 (0.28)**	**-7.23 (0.16)**	**-8.84 (-3.04)**
Difference Effect Size (*r*)	0.63	0.65	0.85	0.96	0.92
% within ± 5 points	81.97%	78.36%	31.15%	21.31%	17.38%
% 3 classifications higher	--	--	--	--	--
% 2 classifications higher	--	1.31%	--	--	--
% 1 classification higher	7.21%	35.08%	1.97%	--	--
% within same classification	65.57%	63.61%	45.25%	45.57%	31.80%
% 1 classification lower	27.21%	--	52.79%	54.43%	63.61%
% 2 classifications lower	--	--	--	--	4.59%
% 3 classifications lower	--	--	--	--	--
% within ± 5 points or same classification	88.85%	81.64%	51.15%	50.49%	33.11%
Spain*					
Mean (*SD*)	117.57 (12.19)	126.02 (12.17)	106.97 (13.85)	108.49 (14.05)	109.94 (11.91)
Standard Error	0.70	0.70	0.79	0.80	0.68
Mean Difference (*SD*)	**-2.74 (3.38)**	**7.18 (2.32)**	**-10.56 (3.04)**	**-9.80 (2.20)**	**-11.22 (0.10)**
Difference Effect Size (*r*)	0.47	0.85	0.86	0.92	0.97
% within ± 5 points	56.72%	35.08%	24.59%	19.02%	4.26%
% 3 classifications higher	--	--	5.90%	--	--
% 2 classifications higher	--	4.26%	20.33%	--	--
% 1 classification higher	9.84%	53.11%	28.52%	--	--
% within same classification	63.28%	42.62%	29.84%	27.54%	20.98%
% 1 classification lower	26.89%	--	12.13%	65.57%	67.21%
% 2 classifications lower	--	--	3.28%	6.89%	11.80%
% 3 classifications lower	--	--	--	--	--
% within ± 5 points or same classification	76.07%	54.43%	50.16%	36.07%	22.62%
USA*					
Mean (*SD*)	112.74 (10.76)	113.62 (10.93)	110.27 (11.45)	105.20 (13.16)	110.65 (12.16)
Standard Error	0.61	0.63	0.66	0.75	0.70
Mean Difference (*SD*)	**-7.57 (1.86)**	**-5.23 (1.08)**	**-7.26 (0.63)**	**-13.08 (1.32)**	**-10.51 (0.16)**
Difference Effect Size (*r*)	0.85	0.74	0.88	0.97	0.94
% within ± 5 points	56.72%	44.59%	30.82%	1.64%	15.08%
% 3 classifications higher	--	--	--	--	--
% 2 classifications higher	--	--	--	--	--
% 1 classification higher	1.64%	4.59%	0.33%	--	--
% within same classification	41.31%	51.80%	39.02%	10.16%	30.49%
% 1 classification lower	53.77%	40.66%	56.72%	75.41%	60.66%
% 2 classifications lower	3.28%	2.95%	3.93%	14.43%	8.85%
% 3 classifications lower	--	--	--	--	--
% within ± 5 points or same classification	74.43%	58.69%	47.54%	10.82%	33.11%
Canada*					
Mean (*SD*)	108.87 (11.73)	111.23 (11.78)	106.56 (12.23)	100.18 (14.03)	108.14 (13.10)
Standard Error	0.67	0.68	0.70	0.80	0.75
Mean Difference (*SD*)	**-11.43 (2.92)**	**-7.62 (1.93)**	**-10.97 (1.42)**	**-18.10 (2.19)**	**-13.01 (1.10)**
Difference Effect Size (*r*)	0.93	0.89	0.94	0.98	0.96
% within ± 5 points	11.80%	31.80%	14.75%	0.33%	1.64%
% 3 classifications higher	--	--	--	--	--
% 2 classifications higher	--	--	--	--	--
% 1 classification higher	--	0.66%	--	--	--
% within same classification	17.70%	39.67%	24.59%	1.97%	12.79%
% 1 classification lower	71.80%	57.05%	64.26%	58.36%	68.20%
% 2 classifications lower	10.49%	2.62%	11.15%	38.03%	19.02%
% 3 classifications lower	--	--	--	1.64%	--
% within ± 5 points or same classification	20.98%	50.16%	28.52%	1.97%	13.77%

*Differences are *Country Norms* minus Colombian Norms; negative values indicate lower scores using non-Colombian norms. Bolded values indicate that the mean differences is significant (p<.0005). Effect size (r)=$\sqrt{}$ ($F(1,df_R)$/ ($F(1,df_R)+df_R$)).

Table 1.5. Select country norms systems descriptive statistics, mean differences, and percentage agreement with Colombian norms for FSIQ and Indices (N=305)

	Colombia	Chile	Mexico	Spain	USA	Canada
Total (*N*)	156	887	1,450	1,002	2,200	688
% Women	50%	50%	51.90%	52.30%	52.20%	53.30%
Average age M (SD)	--	--	46.4 (22.1)	--	45.0 (22.9)	42.8 (21.5)
16 to 17	7.70%	8.60%	5.90%	10.00%	9.10%	9%
18 to 19	7.70%	8.50%	6.10%	9.90%	9.10%	9%
20 to 24	7.70%	8.80%	13.30%	9.90%	9.10%	9%
25 to 29	7.70%	8.00%	7.20%	10.10%	9.10%	9%
30 to 34	7.70%	8.80%	5.00%		9.10%	9%
35 to 44	7.70%	8.30%	10.80%	10.60%	9.10%	9%
45 to 54	7.70%	8.20%	10.50%	10.00%	9.10%	9%
55 to 64	7.70%	9.10%	17.70%	13.80%	9.10%	9%
65 to 69	7.70%	7.40%	6.60%		9.10%	9%
70 to 74	7.70%	7.80%	3.40%	12.30%	4.50%	5%
75 to 79	7.70%	5.50%	5.90%		4.50%	5%
80 to 84	7.70%	6.20%	2.00%	6.79%	4.50%	5%
85 to 90	7.70%	4.70%	5.70%	6.79%	4.50%	5%
Approximate Education Level % [2]						
No Education (ISCED 0: Pre-primary) Primary Education (ISCED 1: Elementary)	33.3% Low SES (strata 1-2) approx. < 8 years	33.1% Low SES (strata 1-2) approx. < 8 years	--	19.3% no education 24.7% primary education	6.6% < secondary education ≤ 8 years 9.3% < secondary education 9-11 years	18.0% < secondary education ≤ 11 years
Secondary Education (ISCED 2-3: Compulsory/ High School)	33.3% Medium SES (strata 3-4) approx. 9-17 years	35.4% Medium SES (strata 3-4) approx. 9-17 years	--	46.9% secondary education	31.4% high school complete 12 years	14.7% secondary complete 12-13 years
Tertiary Education (ISCED 4-6: Post-secondary/ Bachelor's and Technical) Tertiary+ Education (ISCED 7-8: Graduate/ Master's and Doctoral)	33.3% High SES (strata 5-6) approx. ≥ 18 years	31.5% High SES (strata 5-6) approx. > 18 years	--	9.1% tertiary education	27.8% college/vocational 13-15 years 24.9% university degree ≥16 years	40.6% college/vocational 13-15 years 26.7% university degree ≥16 years
Geographic Region %	20.5% Popayán 20.5% Manizales 20.5% Cali 38.5% Medellín	44.2% Santiago 16.8% Concepción 8.2% Arica 7.8% Iquique 6.9% Antofagasta 7.2% Temuco 8.9% Punta Arenas	20.5% Distrito Federal 13.7% Hidalgo 12.6% Guanajunato 11.8% Puebla 20.6% Sinaloa 14.8% Nuevo León 6.1% Yucatán	65.1% Urban 17.2% Suburban 17.8% Rural	19.3% North East 23.5% Mid-West 35.6% South 21.7% West	-- West -- Central -- East
Ethnicity % [3]	--	--	--	--	70.0% White 11.8% African American 13.1% Hispanic 3.2% Asian 1.8% Other	-- Caucasian -- Asian -- First Nations -- Other

[1]Percentages calculated based on data reported in each manual. Details available are provided in the cases of insufficient reporting (as indicated by --). [2]Education descriptives from each manual are provided to help with cross-sample comparisons. ISCED = International Standard Classification of Education (UNESCO Institute for Statistics, 2012. *Note*: little information for the Mexican sample was provided; however, the mode among individuals with lower education (ISCED 0-3) was incomplete high school. [3]Construct of ethinicity not included in the development of norms for Colombia, Chile, Mexico, and Spain.

Table 1.6. Norm systems: Descriptive statistics, mean differences and percentage agreement with Colombian norms for WAIS-IV subtests (scaled scores; *N*=305)

Country Norms System	Similarities	Vocbulary	Information	Comprehension	Block Design	Matrix Reasoning	Visual Puzzles	Figure Weights	Picture Completion	Digit Span	Arithmetic	L-N Sequencing	Symbol Search	Coding	Cancellation
Colombia															
Mean (*SD*)	13.59 (2.32)	13.00 (2.10)	12.55 (2.30)	13.60 (2.08)	12.42 (2.57)	13.34 (2.30)	12.75 (2.45)	13.34 (2.43)	12.14 (2.80)	12.62 (2.16)	13.43 (2.73)	12.53 (2.48)	12.90 (2.63)	13.81 (2.47)	11.49 (2.51)
Standard Error	0.13	0.12	0.13	0.12	0.15	0.132	0.14	0.139	0.161	0.123	0.156	0.142	0.15	0.141	0.144
Chile*															
Mean (*SD*)	13.58 (2.31)	13.00 (2.10)	12.55 (2.30)	13.59 (2.08)	12.41 (2.57)	13.34 (2.31)	12.75 (2.45)	13.34 (2.44)	12.13 (2.81)	12.63 (2.16)	13.43 (2.73)	12.54 (2.48)	12.90 (2.63)	13.81 (2.47)	11.48 (2.51)
Standard Error	0.13	0.12	0.13	0.12	0.15	0.13	0.14	0.14	0.16	0.12	0.16	0.14	0.15	0.14	0.14
Mean Difference (*SD* Difference)	-0.01 (-0.01)	-0.01 (0.00)	-0.01 (0.00)	0.00 (0.00)	-0.01 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	-0.01 (0.00)	0.01 (0.00)	0.01 (0.00)	0.01 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
Difference Effect Size (*r*)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
% within ± 1 points	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	92.46%	100.00%	100.00%	100.00%	100.00%
% within same classification	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
% within ± 1 points or same classification	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
Mexico*															
Mean (*SD*)	14.58 (2.06)	12.99 (2.13)	12.82 (2.37)	14.70 (1.97)	12.05 (2.59)	12.20 (2.12)	11.92 (2.34)	12.49 (2.12)	11.52 (2.39)	11.83 (2.38)	12.48 (2.80)	11.79 (2.21)	12.00 (1.93)	12.63 (1.79)	10.73 (1.57)
Standard Error	0.12	0.12	0.14	0.11	0.15	0.121	0.134	0.121	0.137	0.136	0.16	0.127	0.111	0.102	0.09
Mean Difference (*SD* Difference)	**0.99 (-0.26)**	-0.02 (0.03)	**0.26^ (0.07)**	**1.11 (-0.11)**	**-0.37 (0.02)**	**-1.14 (-0.18)**	**-0.83 (-0.11)**	**-0.84 (-0.31)**	**-0.62 (-0.42)**	**-0.79 (0.22)**	**-0.95 (0.07)**	**-0.74 (-0.27)**	**-0.90 (-0.69)**	**-1.18 (-0.68)**	**-0.75 (-0.94)**
Difference Effect Size (*r*)	0.72	0.02	0.43	0.86	0.39	0.91	0.72	0.77	0.57	0.80	0.91	0.67	0.72	0.80	0.56
% within + 1 points	71.48%	98.03%	93.11%	75.74%	95.08%	41.31%	83.93%	83.93%	85.25%	89.51%	92.46%	88.20%	78.69%	69.51%	68.20%
% within same classification	86.23%	94.10%	94.43%	81.97%	84.59%	77.38%	84.59%	82.95%	86.56%	76.07%	85.90%	88.85%	82.62%	81.31%	78.69%
% within + 1 points or same classification	94.75%	100.00%	98.69%	91.15%	96.07%	88.52%	97.38%	98.36%	95.74%	93.77%	97.70%	99.34%	97.70%	97.38%	84.26%
Spain*															
Mean (*SD*)	16.40 (2.42)	14.67 (2.69)	12.07 (2.83)	14.77 (2.44)	10.89 (2.82)	11.20 (2.66)	11.40 (3.01)	11.79 (2.75)	10.88 (3.01)	10.97 (2.60)	12.20 (3.14)	10.88 (2.45)	11.46 (2.41)	12.14 (2.59)	10.84 (2.75)
Standard Error	0.14	0.15	0.16	0.14	0.16	0.152	0.172	0.157	0.172	0.149	0.18	0.14	0.138	0.148	0.158
Mean Difference (*SD* Difference)	**2.81 (0.10)**	**1.67 (0.59)**	**-0.48 (0.53)**	**1.18 (0.36)**	**-1.52 (0.25)**	**-2.14 (0.35)**	**-1.35 (0.56)**	**-1.55 (0.32)**	**-1.26 (0.21)**	**-1.65 (0.44)**	**-1.23 (0.42)**	**-1.65 (-0.04)**	**-1.44 (-0.22)**	**-1.67 (0.13)**	**-0.65 (0.24)**
Difference Effect Size (*r*)	0.92	0.87	0.46	0.83	0.82	0.89	0.73	0.86	0.89	0.91	0.84	0.85	0.91	0.94	0.70
% within ± 1 points	11.80%	34.10%	85.90%	68.85%	40.66%	30.82%	51.80%	39.02%	67.87%	42.30%	60.98%	37.05%	52.79%	35.08%	92.79%
% within same classification	73.77%	81.97%	61.31%	83.93%	68.20%	60.00%	69.51%	67.21%	77.05%	66.89%	76.07%	73.11%	69.51%	64.59%	89.18%
% within ± 1 points or same classification	73.77%	88.52%	94.43%	95.74%	69.84%	72.79%	79.67%	71.48%	85.57%	69.84%	84.59%	78.03%	79.02%	67.87%	96.72%
USA*															
Mean (*SD*)	12.62 (2.31)	12.09 (2.07)	12.71 (2.68)	13.01 (2.38)	11.65 (2.54)	12.18 (2.50)	11.67 (2.73)	12.45 (2.84)	10.70 (2.91)	10.14 (2.43)	11.78 (3.00)	10.53 (2.21)	11.69 (2.75)	12.23 (2.50)	11.50 (2.59)
Standard Error	0.13	0.12	0.15	0.14	0.15	0.143	0.156	0.162	0.166	0.139	0.172	0.126	0.157	0.143	0.148
Mean Difference (*SD* Difference)	**-0.98 (-0.01)**	**-0.91 (-0.03)**	**0.15 (0.38)**	**-0.59 (0.30)**	**-0.77 (-0.02)**	**-1.16 (0.20)**	**-1.09 (0.28)**	**-0.89 (0.41)**	**-1.44 (0.11)**	**-2.48 (0.27)**	**1-.64 (0.27)**	**-2.00 (-0.28)**	**-1.21 (0.12)**	**-1.58 (0.03)**	0.01 (0.08)
Difference Effect Size (*r*)	0.68	0.68	0.19	0.57	0.64	0.89	0.73	0.72	0.90	0.95	0.92	0.83	0.86	0.89	0.03
% within ± 1 points	57.05%	68.85%	95.08%	83.28%	78.69%	75.08%	67.21%	79.34%	64.92%	11.15%	40.98%	34.10%	62.95%	40.00%	100.00%
% within same classification	82.30%	72.46%	93.44%	83.93%	78.03%	78.69%	75.41%	79.34%	73.77%	45.90%	67.54%	66.23%	75.41%	70.16%	95.74%
% within ± 1 points or same classification	84.92%	84.92%	100.00%	89.51%	88.52%	87.87%	89.51%	90.82%	82.95%	48.20%	73.77%	67.54%	83.28%	75.74%	100.00%
Canada*															
Mean (*SD*)	12.24 (2.41)	11.47 (2.17)	12.32 (2.91)	12.45 (2.44)	10.98 (2.72)	11.66 (2.67)	10.69 (2.65)	11.92 (2.97)	10.55 (3.12)	9.27 (2.55)	10.97 (3.01)	10.02 (2.27)	11.20 (2.92)	11.69 (2.48)	11.46 (2.76)
Standard Error	0.14	0.12	0.15	0.14	0.16	0.153	0.152	0.17	0.178	0.146	0.172	0.13	0.167	0.142	0.158
Mean Difference (*SD* Difference)	**-1.35 (0.09)**	**-1.54 (0.07)**	**-0.24 (0.61)**	**-1.15 (0.36)**	**-1.44 (0.15)**	**-1.68 (0.37)**	**-2.06 (0.20)**	**-1.42 (0.53)**	**-1.59 (0.32)**	**-3.35 (0.39)**	**-2.46 (0.28)**	**-2.51 (-0.21)**	**-1.70 (0.30)**	**-2.12 (0.01)**	-0.02 (0.25)
Difference Effect Size (*r*)	0.86	0.90	0.25	0.82	0.86	0.92	0.92	0.88	0.93	0.98	0.96	0.91	0.93	0.94	0.02
% within ± 1 points	45.25%	44.59%	94.75%	63.28%	44.92%	37.05%	67.21%	54.75%	48.20%	0.33%	40.98%	16.39%	35.41%	20.66%	99.02%
% within same classification	79.34%	64.59%	90.16%	79.02%	67.87%	67.54%	56.39%	70.49%	71.48%	30.82%	53.11%	53.77%	66.56%	61.31%	92.79%
% within ± 1 points or same classification	82.62%	73.77%	99.34%	81.97%	71.48%	72.79%	82.30%	78.36%	78.36%	30.82%	65.90%	53.77%	71.48%	65.25%	99.34%

*Differences are Country Norms minus Colombian Norms; negative values indicate lower scores using non-Colombian norms. Bolded values indicate that the mean difference is significant (all values $p<.0005$ unless denoted by ^ which indicates $p=0.01$). Effect size $(r)=\sqrt{(F(1,df_R)/(F(1,df_R)+df_R))}$. -- indicates effect sizes that could not be calculated.

Table 2.1. Summary of WAIS-IV factor analytic studies

First Author	Year	Country/Test Version	Sample	Age (years)	Method	# WAIS-IV Subtests	# of Models Tested	Four-factor vs. Five-factor Model	Higher-order vs. Bifactor	Final Model
Abdelhamid	2017	Egypt	Community Sample	18 to 24	CFA	10	17	four-factor (though both acceptable)	higher-order	Four-factor (VCI = SI, VC, IN; PRI = BD, MR, VP, AR; WMI = AR, DS; PSI = SS, CD).
Benson	2010	USA	Standardization Sample	16-69	CFA	15	11	five-factor	higher-order (bifactor not tested)	Five-factors (Gc = SI, VC, IN, CO; Gv = BD, VP, PC; Gf = MR, FW, AR; Gsm = DS, AR, LN; Gs = SS, CD, CN).
Canivez	2010a	USA	Standardization Sample	16-19	EFA	10 and 15	--	four-factor	higher-order (bifactor not tested)	General factor + limited support for 4 factors.
Canivez	2010b	USA	Standardization Sample	16-90	EFA	15 (ages 16-69) 12 (ages 70-90)	--	four-factor	higher-order (bifactor not tested)	General factor + limited support for 4 factors.
Frisby	2015	USA	Standardization Sample (white/black)	16-90	EFA CFA	15 WAIS-IV 10 WMS-IV	14	four-factor (five-factor not tested)	bifactor (higher-order not tested)	Bifactor with four broad factors (verbal comprehension, processing speed, visual processing, working memory, correlation FW with AR).
Gignac	2013	USA	Standardization Sample	16-69	CFA	15	4	four-factor	bifactor	Bifactor four-factor Wechsler model with no cross-loadings (VCI = SI, VC, IN, CO; PRI - BD, MR, VP, FW, PC; WMI = DS, AR, LN; PSI = SS, CD, CA).
Gignac	2014	USA	Standardization Sample	16-90	CFA	6 and 17 (DS broken into DSF, DSB, DSS)	5	two-factor and four-factor (five-factor not tested)	Bifactor	Gf and WMC share approx. 60% trude common variance; Gf better predictor of g than WMC.
Niileksela	2013	USA	Standardization Sample	70-90	CFA	14 (DS broken into DSF, DSB, DSS)	10	five-factor	both higher-order and bifactor	Five factor CHC model modified for older population (Gc= SI, VC, IN, CO; Gv = BD, VP, PC; Gf = MR, AR; Gsm = DS forward, backward, sequencing; Gs = CD, SS).
Pezzuti	2018	Italy	Standardization Sample	16-90	CFA	15	1	five-factor (four-factor not tested)	higher-order (bifactor not tested)	Weiss et al. 2013 five-factor model (Gc/VCI = SI, VC, IN, CO; Gv/POI = BD, MR, VP, FW, PC; Gf/FRI = MR, RQ (= FW, AR); Gsm/WMI = DS, AR, LN; Gs/PSI = SS, CD, CA).
Staffaroni	2018	USA	Clinical Sample (Veterans)	Adults	CFA	12 (DS broken into DSF, DSB, DSS)	7	five-factor (though both acceptable)	oblique (favored over higher-order and bifactor)	Five-factor (Gc/VCI = SI, VC, IN, CO; Gv/PRI = BD, PC, VP; Gf/FRI = MR, AR; Gsm/WMI = DS forward, backward, sequencing; Gs/PSI = SS, CD).
van Aken	2017	Netherlands	Clinical Sample	Adults	CFA	15	21	five-factor (though both acceptable)	higher-order (bifactor not tested)	Five-factor (Gc = SI, VC, IN, CO; Gv = BD, MR, VP, FW, PC; Gf = MR, FW, AR; Gsm = DS, AR, LN; Gs = SS, CD, CA; corr. VC with IN, FW with AR).
Ward	2012	USA	Standardization Sample	Adults	CFA	15	5	five-factor (though both acceptable)	oblique (higher-order and bifactor not tested)	Five-factor (Gc = SI, VC, IN, CO, AR; Gv = BD, VP, FW, PC; Gf = MR, FW, AR; Gsm = DS, AR, LN; Gs = SS, CD, CA).
Weiss	2013b	USA	Standardiization Sample & WAIS-IV Clinical Sample	16-69	CFA	15	21	five-factor (though both acceptable)	higher-order (bifactor not tested)	Five-factor (VCI/Gc = SI, VC, IN, CO; POI/Gv = BD, MR, VP, FW, PC; FRI/Gf = MR, RQ (= FW, AR); WMI/Gsm = DS, AR, LN; PSI/Gs = SS, CD, CA).

Table 2.2. Model specifications denoting which subtests were used to indicate each factor

Model	SI	VC	IN	CO	BD	MR	VP	FW	PC	DS	AR	LN	SS	CD	CN	RQ
Four-factor A	VCI	VCI	VCI	VCI	PRI	PRI	PRI	PRI	PRI	WMI	WMI	WMI	PSI	PSI	PSI	--
Four-factor B	VCI	VCI	VCI	VCI	PRI	PRI	PRI	PRI	PRI	WMI*	WMI	WMI*	PSI	PSI	PSI	--
Four-factor C	VCI	VCI	VCI	VCI	PRI	PRI	PRI	PRI, WMI	PRI	WMI*	WMI	WMI*	PSI	PSI	PSI	--
Four-factor D	VCI	VCI	VCI	VCI	PRI	PRI	PRI	PRI	PRI	WMI*	VCI, WMI	WMI*	PSI	PSI	PSI	--
Four-factor E	VCI	VCI	VCI	VCI	PRI	PRI	PRI	PRI, WMI	PRI	WMI*	VCI, WMI	WMI*	PSI	PSI	PSI	--
Five-factor A	Gc	Gc	Gc	Gc	Gv	Gf	Gv	Gf	Gv	Gsm	Gf, Gsm	Gsm	Gs	Gs	Gs	--
Five-factor B	Gc	Gc	Gc	Gc	Gv	Gf	Gv	Gf	Gv	Gsm	Gf, Gc, Gsm	Gsm	Gs	Gs	Gs	--
Five-factor C	Gc	Gc	Gc	Gc	Gv	Gv, Gf	Gv	Gv, RQ	Gv	Gsm	Gsm, RQ	Gsm	Gs	Gs	Gs	Gf
Five-factor D	Gc	Gc	Gc	Gc	Gv	Gv, Gf	Gv	Gv, RQ	Gv	Gsm	Gc, Gsm, RQ	Gsm	Gs	Gs	Gs	Gf

Note. SI = Similarities, VC = Vocabulary, IN = Information, CO = Comprehension, BD = Block Design, MR = Matrix Reasoning, VP = Visual Puzzles, FW = Figure Weights, PC = Picture Completion, DS = Digit Span, AR = Arithmetic, LN = Letter-Number Sequencing, SS = Symbol Search, CD = Coding, CA = Cancellation, VCI = Verbal Comprehension Index, PRI = Performance Reasoning Index, WMI = Working Memory Index, PSI = Processing Speed Index, Gc = crystalized intelligence, Gf = fluid intelligence, Gv = visual processing, Gsm = short-term memory, Gs = processing speed, RQ = Quantitative Reasoning. * indicates the addition of correlation with other stared indicator.

Table 2.3. Fit statistics of all four- and five-factor models tested

Model	WLMSV χ^2	*(df)*	$\Delta\chi^2$	*p*	RMSEA	RMSEA 90% CI	CFI	TLI	SRMR	AIC	BIC	aBIC
Oblique Models												
1. Four-factor A	296.29	84	--	<0.0005	0.061	[0.054 - 0.069]	0.965	0.956	0.034	45378.45	45608.48	45446.55
2. Four-factor B	237.82	83	-58.47	<0.0005	0.053	[0.045 - 0.061]	0.974	0.968	0.030	45321.99	45556.52	45391.41
3. Four-factor C	219.72	82	-18.11	<0.0005	0.050	[0.042 - 0.058]	0.977	0.971	0.029	45305.88	45544.92	45376.64
4. Four-factor D[1]	232.15	82	12.43	<0.0005	0.052	[0.044 - 0.060]	0.975	0.968	0.030	45318.31	45557.35	45389.07
5. Four-factor E[1]	212.20	81	-19.94	<0.0005	0.049	[0.041 - 0.057]	0.978	0.972	0.029	45300.37	45543.92	45372.47
6. Five-factor A	168.79	79	--	<0.0005	0.041	[0.033 - 0.050]	0.985	0.980	0.026	45260.95	45513.53	45355.72
7. Five-factor B[1]	164.31	78	-4.48	<0.0005	0.041	[0.032 - 0.049]	0.986	0.981	0.025	45258.47	45515.56	45334.58
8. Five-factor C	160.84	77	-3.47	<0.0005	0.040	[0.031 - 0.049]	0.986	0.981	0.025	45257.00	45518.60	45334.44
9. Five-factor D[1]	159.48	76	-1.36	<0.0005	0.040	[0.032 - 0.049]	0.986	0.981	0.025	45257.64	45523.75	45336.42
Higher-Order Models												
10. Four-factor A	296.94	86	--	<0.0005	0.060	[0.053 - 0.068]	0.965	0.957	0.034	45375.10	45596.11	45440.53
11. Four-factor B	238.24	85	-58.70	<0.0005	0.052	[0.044 - 0.060]	0.975	0.969	0.030	45318.41	45543.92	45385.17
12. Four-factor C	**219.72**	**84**	**-18.52**	**<0.0005**	**0.049**	**[0.041 - 0.057]**	**0.978**	**0.972**	**0.029**	**45301.89**	**45531.91**	**45369.98**
13. Four-factor D[1]	--	--	--	--	--	--	--	--	--	--	--	--
14. Four-factor E[1]	--	--	--	--	--	--	--	--	--	--	--	--
15. Five-factor A	193.70	84	--	<0.0005	0.044	[0.036 - 0.052]	0.982	0.977	0.028	45275.86	45505.89	45343.96
16. Five-factor B[1]	--	--	--	--	--	--	--	--	--	--	--	--
17. Five-factor C	**181.89**	**82**	**-11.81**	**<.0005**	**0.043**	**[0.034 - 0.051]**	**0.984**	**0.979**	**0.027**	**45268.05**	**45507.10**	**45338.82**
18. Five-factor D[1]	--	--	--	--	--	--	--	--	--	--	--	--
Bifactor Models												
19. Four-factor A	120.03	69	--	0.0001	0.033	[0.023 - 0.043]	0.992	0.987	0.019	45232.19	45529.87	45320.31
20. Four-factor B[2]	116.32	68	-3.71	0.0002	0.033	[0.022 - 0.042]	0.992	0.988	0.019	45230.48	45532.67	45319.94
21. Four-factor C[2]	**105.45**	**67**	**-10.87**	**0.0019**	**0.029**	**[0.018 - 0.040]**	**0.994**	**0.990**	**0.018**	**45221.61**	**45528.31**	**45312.40**
22. Four-factor D[1]	--	--	--	--	--	--	--	--	--	--	--	--
23. Four-factor E[1]	--	--	--	--	--	--	--	--	--	--	--	--
24. Five-factor A	92.10	64	--	0.0123	0.026	[0.012 - 0.037]	0.995	0.992	0.016	45214.26	45534.49	45309.06

25. Five-factor B[1]	--	--	--	--	--	--	--	--	--	--	--	--
26. Five-factor C	**87.90**	**62**	**-4.20**	**0.0169**	**0.025**	**[0.011 - 0.036]**	**0.996**	**0.993**	**0.016**	**45214.06**	**45543.31**	**45311.53**
27. Five-factor D[1]	--	--	--	--	--	--	--	--	--	--	--	--

Note. [1] Cross-factor loading of arithmetic (AR) on Verbal Comprehension Index (VCI)/Crystalized intelligence (Gc) is negative; fit statistics are only reported for oblique version of models. [2] Covariance matrix not positive definite. CFI = comparative fit index; RMSEA = root mean square error of approximation; SRMR = standardized root mean square residual; AIC - Akaike information criterion; BIC = Bayesian information criterion; aBCI = adjusted Bayesian information criterion. Specific model structure is denoted in Table 2 and Figures 1 and 2. Best fitting four-factor models are highlighted in blue. Best fitting five-factor models are highlighted in green.

Table 2.4. Factor loadings of the best fitting higher-order and bifactor models (five-factor model C)

	g		Gc			Gv			Gf (RQ)			Gsm			Gs		
Subtest	SL Trans.	Bifactor	Higher-Order	SL Trans.	Bifactor	Higher-Order	SL Trans.	Bifactor	Higher-Order	SL Trans.	Bifactor	Higher-Order	SL Trans.	Bifactor	Higher-Order	SL Trans.	Bifactor
SI	0.702	0.801	0.802	0.388	0.063												
VC	0.762	0.868	0.871	0.422	0.061												
IN	0.728	0.840	0.832	0.403	-0.221												
CO	0.707	0.820	0.808	0.391	0.178												
BD	0.702	0.593				0.802	0.388	0.554									
MR	0.586	0.681				0.193	--	0.068	0.586	0.000	0.283						
VP	0.671	0.555				0.767	0.371	0.557	(0.692)	--	(0.365)						
FW	0.126	0.671				0.144	0.070	0.080									
PC	0.592	0.582				0.676	0.327	0.317									
DS	0.725	0.629										0.874	0.487	0.630			
AR	0.217	0.628							(0.566)	--	(0.423)	0.261	0.146	0.131			
LN	0.402	0.633										0.484	0.270	0.546			
SS	0.662	0.490													0.874	0.571	0.697
CD	0.198	0.584													0.261	0.171	0.531
CN	0.366	0.379													0.484	0.316	0.438
(RQ)	0.931	--							0.931	0.000	0.854						
Avg.	0.567	0.650	0.828	0.401	0.020	0.516	0.289	0.315	0.759	0.000	0.569	0.540	0.301	0.436	0.540	0.353	0.555

Note. SL Trans. = Schmid-Leiman transformation (Schmid & Leiman, 1957; Brown, 2015). SI = Similarities, VC = Vocabulary, IN = Information, CO = Comprehension, BD = Block Design, MR = Matrix Reasoning, VP = Visual Puzzles, FW = Figure Weights, PC = Picture Completion, DS = Digit Span, AR = Arithmetic, LN = Letter-Number Sequencing, SS = Symbol Search, CD = Coding, CA = Cancellation, VCI = Verbal Comprehension Index, PRI = Performance Reasoning Index, WMI = Working Memory Index, PSI = Processing Speed Index, Gc = crystalized intelligence, Gf = fluid intelligence, Gv = visual processing, Gsm = short-term memory, Gs = processing speed, RQ = Quantitative Reasoning.

Table 3.1 Reliability, Validity, and Clinical Correspondence of Best 2-, 3-, 4-, and 5-Subtest Short Forms

T1	T2	T3	T4	T5	r_{ss}	r	% est. IQs within ±2 pts	% est. IQs within ±5 pts	% est. IQs within ±10 pts	% within same clinical classifications	% within ±1 clinical classification	% within ±2 clinical classifications	Suppl. Test?	Model Align.
Two-subtests														
IN	MR[1]	-	-	-	0.941	0.857	27.06	57.84	84.10	59.53	36.53	3.95		W
IN	DS[2]	-	-	-	0.938	0.864	24.69	55.02	84.67	60.43	36.75	2.82		CHC
VC	MR[3]	-	-	-	0.934	0.860	28.97	57.05	85.23	58.06	38.67	3.27		W
VC	DS[4]	-	-	-	0.932	0.859	25.59	54.11	83.99	59.41	37.66	2.93		CHC
IN	VP[5]	-	-	-	0.925	0.849	26.83	52.99	83.09	57.61	39.23	3.16		W
MR	DS[6]	-	-	-	0.923	0.848	24.92	49.49	80.61	58.29	38.67	3.04		CHC
VC	LN[7]	-	-	-	0.918	0.863	18.38	39.01	61.78	44.65	27.73	3.38	*	CHC
				Mean:	**0.930**	**0.857**	**25.21**	**52.21**	**80.50**	**56.85**	**36.46**	**3.22**		
Three-subtests														
IN	VP	DS[5]	-	-	0.945	0.880	33.82	67.19	93.12	66.97	32.13	0.90		W
IN	MR	DS[6]	-	-	0.952	0.893	31.23	62.80	91.43	65.61	33.26	1.13		W
VC	VP	DS[7]	-	-	0.941	0.883	31.79	66.40	92.45	66.85	32.47	0.68		W
VC	MR	DS[8]	-	-	0.948	0.898	33.82	65.50	92.33	66.52	32.36	1.13		W
VC	MR	VP[9]	-	-	0.940	0.902	31.68	60.20	90.53	64.15	34.84	1.01		CHC
SI	MR	DS[10]	-	-	0.930	0.896	32.58	63.13	91.77	62.80	36.30	0.90		W
VC	MR	LN[11]	-	-	0.941	0.903	29.76	61.61	89.73	61.16	37.50	1.34	*	W
				Mean:	**0.943**	**0.894**	**32.10**	**63.83**	**91.62**	**64.87**	**34.12**	**1.01**		

Four-subtests														
VC	BD	MR	DS[12]	-	0.946	0.923	41.38	77.68	97.52	74.18	25.59	0.23		CHC
VC	IN	VP	DS[13]	-	0.958	0.924	41.38	72.49	95.72	72.83	26.72	0.45		W
SI	IN	BD	DS[14]	-	0.951	0.924	38.22	73.28	97.18	72.04	27.62	0.34		W
IN	MR	VP	DS[15]	-	0.956	0.918	40.47	70.12	95.60	70.12	29.43	0.45		CHC
SI	MR	VP	DS[16]	-	0.952	0.921	37.09	72.83	95.60	70.01	29.76	0.23		CHC
VC	MR	PC	DS[17]	-	0.949	0.921	34.05	66.18	92.90	69.67	29.20	1.13	*	CHC
VC	IN	VP	LN[18]	-	0.954	0.924	35.86	69.49	92.56	69.05	30.21	0.74	*	W
SI	IN	MR	LN[19]	-	0.960	0.915	35.57	67.11	91.52	64.58	34.08	1.34	*	W
				Mean:	**0.953**	**0.921**	**38.00**	**71.15**	**94.82**	**70.31**	**29.08**	**0.61**		
Five-subtests														
VC	IN	VP	DS	SS[22]	0.931	0.942	51.97	85.34	99.10	79.14	20.86			W
VC	IN	MR	DS	SS[23]	0.937	0.939	47.01	81.51	98.87	75.76	24.13	0.11		W
VC	IN	BD	MR	LN[24]	0.937	0.935	41.22	75.15	95.83	69.94	29.61	0.45	*	CHC
SI	VC	MR	PC	DS[25]	0.930	0.939	39.12	69.56	95.72	69.00	30.21	0.79	*	CHC
VC	IN	MR	PC	DS[26]	0.944	0.933	34.50	69.90	95.49	68.43	31.12	0.45	*	CHC
VC	IN	MR	PC	LN[27]	0.940	0.931	35.27	65.63	92.71	66.82	31.55	1.64	*	CHC
				Mean:	**0.936**	**0.936**	**41.52**	**74.51**	**96.29**	**71.51**	**27.91**	**0.69**		

Note. T = subtest (T1-T5), r_{ss} = Pearson reliability coefficient, *r* = validity coefficient, Vc SI = Similarities, VC = Vocabulary, IN = Information, CO = Comprehension, BD = Block Design, MR = Matrix Reasoning, VP = Visual Puzzles, PC = Picture Completion, DS = Digit Span, LN = Letter-Number Sequencing, SS = Symbol Search. * Contains a supplemental test which may not be ideal for some assessment situations. W = Combinations most theoretically consistent with the Wechsler (4-factor) model. CHC = Combinations most theoretically consistent with the Cattell-Horn Carroll (CHC 5-factor) model. [1-7]two-subtest combinations C1, C2, C3, C4, C5, C7, and C8 respectively. [5-11]three-subtest combinations C9, C2, C10, C4, C8, and C3 respectively. [12-19]four-fubtest combinations C23, C7, C19, C10, C16, C20, C12, and C5, respectively. [22-27]five-subtest combinations C24, C16, C18, C25, C6 and C12 respectively (see Supplemental Table 2 for a full list of numbered combinations).

Table 3.2. Estimated WAIS-IV Full Scale IQs and 95% confidence intervals for Sum of Scaled Scored for the Best 2-Subtest Short Forms

	IN + MR[1]			IN + DS[2]			VC + MR[3]			VC + DS[4]			IN + VP[5]			MR + DS[6]			VC + LN[7]			
sum of scaled scores	*Reliable range = 2*			*Reliable range = 2*			*Reliable range = 2*			*Reliable range = 2*			*Reliable range = 2*			*Reliable range = 2*			*Reliable range = 2*			sum of scaled scores
	est. IQ	95% lower	95% upper	est. IQ	95% lower	95% upper	est. IQ	95% lower	95% upper	est. IQ	95% lower	95% upper	est. IQ	95% lower	95% upper	est. IQ	95% lower	95% upper	est. IQ	95% lower	95% upper	
2	50	46	54	50	46	54	50	46	54	50	46	54	48	44	52	48	44	52	48	44	52	**2**
3	52	48	56	52	48	56	52	48	56	52	48	56	51	47	55	51	47	55	51	47	55	**3**
4	55	51	59	55	51	59	55	51	59	55	51	59	54	50	58	54	50	58	54	50	58	**4**
5	58	54	62	58	54	62	58	54	62	58	54	62	57	53	60	57	53	60	57	53	60	**5**
6	61	57	65	61	57	65	61	57	65	61	57	65	59	55	63	59	55	63	59	55	63	**6**
7	64	60	68	64	60	68	64	60	68	64	60	68	62	58	66	62	58	66	62	58	66	**7**
8	66	62	70	66	62	70	66	62	70	66	62	70	65	61	69	65	61	69	65	61	69	**8**
9	69	65	73	69	65	73	69	65	73	69	65	73	68	64	72	68	64	72	68	64	72	**9**
10	72	68	76	72	68	76	72	68	76	72	68	76	71	67	75	71	67	75	71	67	75	**10**
11	75	71	79	75	71	79	75	71	79	75	71	79	74	70	78	74	70	78	74	70	78	**11**
12	78	74	82	78	74	82	78	74	82	78	74	82	77	73	81	77	73	81	77	73	81	**12**
13	80	76	84	80	76	84	80	76	84	80	76	84	80	76	84	80	76	84	80	76	84	**13**
14	83	79	87	83	79	87	83	79	87	83	79	87	83	79	87	83	79	87	83	79	87	**14**
15	86	82	90	86	82	90	86	82	90	86	82	90	86	82	89	86	82	89	86	82	89	**15**
16	89	85	93	89	85	93	89	85	93	89	85	93	88	84	92	88	84	92	88	84	92	**16**
17	92	88	96	92	88	96	92	88	96	92	88	96	91	87	95	91	87	95	91	87	95	**17**
18	94	90	98	94	90	98	94	90	98	94	90	98	94	90	98	94	90	98	94	90	98	**18**
19	97	93	101	97	93	101	97	93	101	97	93	101	97	93	101	97	93	101	97	93	101	**19**
20	100	96	104	100	96	104	100	96	104	100	96	104	100	96	104	100	96	104	100	96	104	**20**
21	103	99	107	103	99	107	103	99	107	103	99	107	103	99	107	103	99	107	103	99	107	**21**
22	106	102	110	106	102	110	106	102	110	106	102	110	106	102	110	106	102	110	106	102	110	**22**
23	108	104	112	108	104	112	108	104	112	108	104	112	109	105	113	109	105	113	109	105	113	**23**
24	111	107	115	111	107	115	111	107	115	111	107	115	112	108	116	112	108	116	112	108	116	**24**
25	114	110	118	114	110	118	114	110	118	114	110	118	115	111	118	115	111	118	115	111	118	**25**
26	117	113	121	117	113	121	117	113	121	117	113	121	117	113	121	117	113	121	117	113	121	**26**
27	120	116	124	120	116	124	120	116	124	120	116	124	120	116	124	120	116	124	120	116	124	**27**
28	122	118	126	122	118	126	122	118	126	122	118	126	123	119	127	123	119	127	123	119	127	**28**
29	125	121	129	125	121	129	125	121	129	125	121	129	126	122	130	126	122	130	126	122	130	**29**
30	128	124	132	128	124	132	128	124	132	128	124	132	129	125	133	129	125	133	129	125	133	**30**
31	131	127	135	131	127	135	131	127	135	131	127	135	132	128	136	132	128	136	132	128	136	**31**
32	134	130	138	134	130	138	134	130	138	134	130	138	135	131	139	135	131	139	135	131	139	**32**
33	136	132	140	136	132	140	136	132	140	136	132	140	138	134	142	138	134	142	138	134	142	**33**
34	139	135	143	139	135	143	139	135	143	139	135	143	141	137	145	141	137	145	141	137	145	**34**
35	142	138	146	142	138	146	142	138	146	142	138	146	144	140	147	144	140	147	144	140	147	**35**
36	145	141	149	145	141	149	145	141	149	145	141	149	146	142	150	146	142	150	146	142	150	**36**
37	148	144	152	148	144	152	148	144	152	148	144	152	149	145	153	149	145	153	149	145	153	**37**
38	150	146	154	150	146	154	150	146	154	150	146	154	152	148	156	152	148	156	152	148	156	**38**

Note: IN = information, MR = Matrix reasoning, DS = Digit span, VC = MR, VC = Vocabulary, VP = Visual puzzles, LN = Letter-number sequencing; [1-7]two-subtest combination numbers C1, C2, C3, C4, C5, C7, and C8 in the derivation process, respectively (also numbered to correspond Supplemental Table 2).

Table 3.3. Estimated WAIS-IV Full Scale IQs and 95% confidence intervals for Sum of Scaled Scored for the Best 3-Subtest Short Forms

Subtests:	IN + VP + DS[1]			IN + MR + DS[2]			VC + VP + DS[3]			VC + MR +DS[4]			VC + MR + VP[5]			SI + MR + DS[6]			VC + MR+ LN[7]			
	Reliable range = 2 Unusual range = 7			*Reliable range = 2 Unusual range = 8*			*Reliable range = 2 Unusual range = 7*			*Reliable range = 2 Unusual range = 8*			*Reliable range = 2 Unusual range = 7*			*Reliable range = 2 Unusual range = 7*			*Reliable range = 2 Unusual range = 8*			
Sum of scaled scores	est. IQ	95% CI lower	95% CI upper	est. IQ	95% CI lower	95% CI upper	est. IQ	95% CI lower	95% CI upper	est. IQ	95% CI lower	95% CI upper	est. IQ	95% CI lower	95% CI upper	est. IQ	95% CI lower	95% CI upper	est. IQ	95% CI lower	95% CI upper	Sum of scaled scores
3	46	42	50	46	42	50	46	42	50	46	42	50	43	39	47	46	42	50	46	42	50	**3**
4	48	44	52	48	44	52	48	44	52	48	44	52	45	41	49	48	44	52	48	44	52	**4**
5	50	46	54	50	46	54	50	46	54	50	46	54	48	44	51	50	46	54	50	46	54	**5**
6	52	48	56	52	48	56	52	48	56	52	48	56	50	46	54	52	48	56	52	48	56	**6**
7	54	50	58	54	50	58	54	50	58	54	50	58	52	48	56	54	50	58	54	50	58	**7**
8	56	52	60	56	52	60	56	52	60	56	52	60	54	50	58	56	52	60	56	52	60	**8**
9	58	54	62	58	54	62	58	54	62	58	54	62	56	52	60	58	54	62	58	54	62	**9**
10	60	56	64	60	56	64	60	56	64	60	56	64	58	54	62	60	56	64	60	56	64	**10**
11	62	58	66	62	58	66	62	58	66	62	58	66	60	56	64	62	58	66	62	58	66	**11**
12	64	60	68	64	60	68	64	60	68	64	60	68	62	58	66	64	60	68	64	60	68	**12**
13	66	62	70	66	62	70	66	62	70	66	62	70	64	60	68	66	62	70	66	62	70	**13**
14	68	64	72	68	64	72	68	64	72	68	64	72	66	62	70	68	64	72	68	64	72	**14**
15	70	66	74	70	66	74	70	66	74	70	66	74	69	65	72	70	66	74	70	66	74	**15**
16	72	68	76	72	68	76	72	68	76	72	68	76	71	67	75	72	68	76	72	68	76	**16**
17	74	70	78	74	70	78	74	70	78	74	70	78	73	69	77	74	70	78	74	70	78	**17**
18	76	72	80	76	72	80	76	72	80	76	72	80	75	71	79	76	72	80	76	72	80	**18**
19	78	74	82	78	74	82	78	74	82	78	74	82	77	73	81	78	74	82	78	74	82	**19**
20	80	76	84	80	76	84	80	76	84	80	76	84	79	75	83	80	76	84	80	76	84	**20**
21	82	78	86	82	78	86	82	78	86	82	78	86	81	77	85	82	78	86	82	78	86	**21**
22	84	80	88	84	80	88	84	80	88	84	80	88	83	79	87	84	80	88	84	80	88	**22**
23	86	82	90	86	82	90	86	82	90	86	82	90	85	81	89	86	82	90	86	82	90	**23**
24	88	84	92	88	84	92	88	84	92	88	84	92	87	83	91	88	84	92	88	84	92	**24**
25	90	86	94	90	86	94	90	86	94	90	86	94	90	86	93	90	86	94	90	86	94	**25**
26	92	88	96	92	88	96	92	88	96	92	88	96	92	88	96	92	88	96	92	88	96	**26**

27	94	90	98	94	90	98	94	90	98	94	90	98	94	90	98	94	90	98	94	90	98	**27**
28	96	92	100	96	92	100	96	92	100	96	92	100	96	92	100	96	92	100	96	92	100	**28**
29	98	94	102	98	94	102	98	94	102	98	94	102	98	94	102	98	94	102	98	94	102	**29**
30	100	96	104	100	96	104	100	96	104	100	96	104	100	96	104	100	96	104	100	96	104	**30**
31	102	98	106	102	98	106	102	98	106	102	98	106	102	98	106	102	98	106	102	98	106	**31**
32	104	100	108	104	100	108	104	100	108	104	100	108	104	100	108	104	100	108	104	100	108	**32**
33	106	102	110	106	102	110	106	102	110	106	102	110	106	102	110	106	102	110	106	102	110	**33**
34	108	104	112	108	104	112	108	104	112	108	104	112	108	104	112	108	104	112	108	104	112	**34**
35	110	106	114	110	106	114	110	106	114	110	106	114	111	107	114	110	106	114	110	106	114	**35**
36	112	108	116	112	108	116	112	108	116	112	108	116	113	109	117	112	108	116	112	108	116	**36**
37	114	110	118	114	110	118	114	110	118	114	110	118	115	111	119	114	110	118	114	110	118	**37**
38	116	112	120	116	112	120	116	112	120	116	112	120	117	113	121	116	112	120	116	112	120	**38**
39	118	114	122	118	114	122	118	114	122	118	114	122	119	115	123	118	114	122	118	114	122	**39**
40	120	116	124	120	116	124	120	116	124	120	116	124	121	117	125	120	116	124	120	116	124	**40**
41	122	118	126	122	118	126	122	118	126	122	118	126	123	119	127	122	118	126	122	118	126	**41**
42	124	120	128	124	120	128	124	120	128	124	120	128	125	121	129	124	120	128	124	120	128	**42**
43	126	122	130	126	122	130	126	122	130	126	122	130	127	123	131	126	122	130	126	122	130	**43**
44	128	124	132	128	124	132	128	124	132	128	124	132	129	125	133	128	124	132	128	124	132	**44**
45	130	126	134	130	126	134	130	126	134	130	126	134	132	128	135	130	126	134	130	126	134	**45**
46	132	128	136	132	128	136	132	128	136	132	128	136	134	130	138	132	128	136	132	128	136	**46**
47	134	130	138	134	130	138	134	130	138	134	130	138	136	132	140	134	130	138	134	130	138	**47**
48	136	132	140	136	132	140	136	132	140	136	132	140	138	134	142	136	132	140	136	132	140	**48**
49	138	134	142	138	134	142	138	134	142	138	134	142	140	136	144	138	134	142	138	134	142	**49**
50	140	136	144	140	136	144	140	136	144	140	136	144	142	138	146	140	136	144	140	136	144	**50**
51	142	138	146	142	138	146	142	138	146	142	138	146	144	140	148	142	138	146	142	138	146	**51**
52	144	140	148	144	140	148	144	140	148	144	140	148	146	142	150	144	140	148	144	140	148	**52**
53	146	142	150	146	142	150	146	142	150	146	142	150	148	144	152	146	142	150	146	142	150	**53**
54	148	144	152	148	144	152	148	144	152	148	144	152	150	146	154	148	144	152	148	144	152	**54**
55	150	146	154	150	146	154	150	146	154	150	146	154	153	149	156	150	146	154	150	146	154	**55**
56	152	148	156	152	148	156	152	148	156	152	148	156	155	151	159	152	148	156	152	148	156	**56**
57	154	150	158	154	150	158	154	150	158	154	150	158	157	153	161	154	150	158	154	150	158	**57**

Note. IN = Information, VP = Visual puzzles, DS = Digit span, MR = Matrix reasoning, VC = Vocabulary, SI = Similarities, LN = Letter-number sequencing. [1-7]three-subtest combination numbers C9, C2, C10, C1, C4, C8, and C3 in the derivation process, respectively (also numbered to correspond Supplemental Table 2).

Table 3.4. Estimated WAIS-IV Full Scale IQs and 95% confidence intervals for Sum of Scaled Scored for the Best 4-Subtest Short Forms

	VC + BD + MR + DS[1]			VC + IN + VP + DS[2]			SI + IN + BD + DS[3]			IN + MR + VP + DS[4]		
	Reliable range = 2 *Unusual range = 8*			*Reliable range = 2* *Unusual range = 8*			*Reliable range = 2* *Unusual range = 8*			*Reliable range = 2* *Unusual range = 8*		
Sum of scaled scores	**est. IQ**	**95% CI lower**	**95% CI upper**	**est. IQ**	**95% CI lower**	**95% CI upper**	**est. IQ**	**95% CI lower**	**95% CI upper**	**est. IQ**	**95% CI lower**	**95% CI upper**
4	42	38	46	42	38	46	42	38	46	42	38	46
5	44	40	48	44	40	48	44	40	48	44	40	48
6	46	42	50	46	42	50	46	42	50	46	42	50
7	47	43	51	47	43	51	47	43	51	47	43	51
8	49	45	53	49	45	53	49	45	53	49	45	53
9	50	46	54	50	46	54	50	46	54	50	46	54
10	52	48	56	52	48	56	52	48	56	52	48	56
11	54	50	58	54	50	58	54	50	58	54	50	58
12	55	51	59	55	51	59	55	51	59	55	51	59
13	57	53	61	57	53	61	57	53	61	57	53	61
14	58	54	62	58	54	62	58	54	62	58	54	62
15	60	56	64	60	56	64	60	56	64	60	56	64
16	62	58	66	62	58	66	62	58	66	62	58	66
17	63	59	67	63	59	67	63	59	67	63	59	67
18	65	61	69	65	61	69	65	61	69	65	61	69
19	66	62	70	66	62	70	66	62	70	66	62	70
20	68	64	72	68	64	72	68	64	72	68	64	72
21	70	66	74	70	66	74	70	66	74	70	66	74
22	71	67	75	71	67	75	71	67	75	71	67	75
23	73	69	77	73	69	77	73	69	77	73	69	77
24	74	70	78	74	70	78	74	70	78	74	70	78
25	76	72	80	76	72	80	76	72	80	76	72	80
26	78	74	82	78	74	82	78	74	82	78	74	82
27	79	75	83	79	75	83	79	75	83	79	75	83
28	81	77	85	81	77	85	81	77	85	81	77	85
29	82	78	86	82	78	86	82	78	86	82	78	86
30	84	80	88	84	80	88	84	80	88	84	80	88
31	86	82	90	86	82	90	86	82	90	86	82	90
32	87	83	91	87	83	91	87	83	91	87	83	91
33	89	85	93	89	85	93	89	85	93	89	85	93
34	90	86	94	90	86	94	90	86	94	90	86	94
35	92	88	96	92	88	96	92	88	96	92	88	96
36	94	90	98	94	90	98	94	90	98	94	90	98
37	95	91	99	95	91	99	95	91	99	95	91	99
38	97	93	101	97	93	101	97	93	101	97	93	101
39	98	94	102	98	94	102	98	94	102	98	94	102

40	100	96	104	100	96	104	100	96	104	100	96	104
41	102	98	106	102	98	106	102	98	106	102	98	106
42	103	99	107	103	99	107	103	99	107	103	99	107
43	105	101	109	105	101	109	105	101	109	105	101	109
44	106	102	110	106	102	110	106	102	110	106	102	110
45	108	104	112	108	104	112	108	104	112	108	104	112
46	110	106	114	110	106	114	110	106	114	110	106	114
47	111	107	115	111	107	115	111	107	115	111	107	115
48	113	109	117	113	109	117	113	109	117	113	109	117
49	114	110	118	114	110	118	114	110	118	114	110	118
50	116	112	120	116	112	120	116	112	120	116	112	120
51	118	114	122	118	114	122	118	114	122	118	114	122
52	119	115	123	119	115	123	119	115	123	119	115	123
53	121	117	125	121	117	125	121	117	125	121	117	125
54	122	118	126	122	118	126	122	118	126	122	118	126
55	124	120	128	124	120	128	124	120	128	124	120	128
56	126	122	130	126	122	130	126	122	130	126	122	130
57	127	123	131	127	123	131	127	123	131	127	123	131
58	129	125	133	129	125	133	129	125	133	129	125	133
59	130	126	134	130	126	134	130	126	134	130	126	134
60	132	128	136	132	128	136	132	128	136	132	128	136
61	134	130	138	134	130	138	134	130	138	134	130	138
62	135	131	139	135	131	139	135	131	139	135	131	139
63	137	133	141	137	133	141	137	133	141	137	133	141
64	138	134	142	138	134	142	138	134	142	138	134	142
65	140	136	144	140	136	144	140	136	144	140	136	144
66	142	138	146	142	138	146	142	138	146	142	138	146
67	143	139	147	143	139	147	143	139	147	143	139	147
68	145	141	149	145	141	149	145	141	149	145	141	149
69	146	142	150	146	142	150	146	142	150	146	142	150
70	148	144	152	148	144	152	148	144	152	148	144	152
71	150	146	154	150	146	154	150	146	154	150	146	154
72	151	147	155	151	147	155	151	147	155	151	147	155
73	153	149	157	153	149	157	153	149	157	153	149	157
74	154	150	158	154	150	158	154	150	158	154	150	158
75	156	152	160	156	152	160	156	152	160	156	152	160
76	158	154	162	158	154	162	158	154	162	158	154	162

SI + MR + VP + DS[5]			VC + MR + PC + DS[6]			VC + IN + VP + LN[7]			SI + IN + MR + LN[8]			
Reliable range = 2 Unusual range = 8			*Reliable range = 2 Unusual range = 8*			*Reliable range = 2 Unusual range = 8*			*Reliable range = 2 Unusual range = 8*			
est. IQ	**95% CI lower**	**95% CI upper**	**est. IQ**	**95% CI lower**	**95% CI upper**	**est. IQ**	**95% CI lower**	**95% CI upper**	**est. IQ**	**95% CI lower**	**95% CI upper**	**Sum of scaled scores**
42	38	46	42	38	46	42	38	46	46	42	50	**4**
44	40	48	44	40	48	44	40	48	48	44	51	**5**
46	42	50	46	42	50	46	42	50	49	45	53	**6**
47	43	51	47	43	51	47	43	51	51	47	54	**7**
49	45	53	49	45	53	49	45	53	52	48	56	**8**
50	46	54	50	46	54	50	46	54	54	50	57	**9**
52	48	56	52	48	56	52	48	56	55	51	59	**10**
54	50	58	54	50	58	54	50	58	57	53	60	**11**
55	51	59	55	51	59	55	51	59	58	54	62	**12**
57	53	61	57	53	61	57	53	61	60	56	63	**13**
58	54	62	58	54	62	58	54	62	61	57	65	**14**
60	56	64	60	56	64	60	56	64	63	59	66	**15**
62	58	66	62	58	66	62	58	66	64	60	68	**16**
63	59	67	63	59	67	63	59	67	66	62	69	**17**
65	61	69	65	61	69	65	61	69	67	63	71	**18**
66	62	70	66	62	70	66	62	70	69	65	72	**19**
68	64	72	68	64	72	68	64	72	70	66	74	**20**
70	66	74	70	66	74	70	66	74	72	68	75	**21**
71	67	75	71	67	75	71	67	75	73	69	77	**22**
73	69	77	73	69	77	73	69	77	75	71	78	**23**
74	70	78	74	70	78	74	70	78	76	72	80	**24**
76	72	80	76	72	80	76	72	80	78	74	81	**25**
78	74	82	78	74	82	78	74	82	79	75	83	**26**
79	75	83	79	75	83	79	75	83	81	77	84	**27**
81	77	85	81	77	85	81	77	85	82	78	86	**28**
82	78	86	82	78	86	82	78	86	84	80	87	**29**
84	80	88	84	80	88	84	80	88	85	81	89	**30**
86	82	90	86	82	90	86	82	90	87	83	90	**31**
87	83	91	87	83	91	87	83	91	88	84	92	**32**
89	85	93	89	85	93	89	85	93	90	86	93	**33**
90	86	94	90	86	94	90	86	94	91	87	95	**34**
92	88	96	92	88	96	92	88	96	93	89	96	**35**
94	90	98	94	90	98	94	90	98	94	90	98	**36**
95	91	99	95	91	99	95	91	99	96	92	99	**37**
97	93	101	97	93	101	97	93	101	97	93	101	**38**
98	94	102	98	94	102	98	94	102	99	95	102	**39**

100	96	104	100	96	104	100	95	105	100	95	105	**40**
102	98	106	102	98	106	102	98	106	102	98	105	**41**
103	99	107	103	99	107	103	99	107	103	99	107	**42**
105	101	109	105	101	109	105	101	109	105	101	108	**43**
106	102	110	106	102	110	106	102	110	106	102	110	**44**
108	104	112	108	104	112	108	104	112	108	104	111	**45**
110	106	114	110	106	114	110	106	114	109	105	113	**46**
111	107	115	111	107	115	111	107	115	111	107	114	**47**
113	109	117	113	109	117	113	109	117	112	108	116	**48**
114	110	118	114	110	118	114	110	118	114	110	117	**49**
116	112	120	116	112	120	116	112	120	115	111	119	**50**
118	114	122	118	114	122	118	114	122	117	113	120	**51**
119	115	123	119	115	123	119	115	123	118	114	122	**52**
121	117	125	121	117	125	121	117	125	120	116	123	**53**
122	118	126	122	118	126	122	118	126	121	117	125	**54**
124	120	128	124	120	128	124	120	128	123	119	126	**55**
126	122	130	126	122	130	126	122	130	124	120	128	**56**
127	123	131	127	123	131	127	123	131	126	122	129	**57**
129	125	133	129	125	133	129	125	133	127	123	131	**58**
130	126	134	130	126	134	130	126	134	129	125	132	**59**
132	128	136	132	128	136	132	128	136	130	126	134	**60**
134	130	138	134	130	138	134	130	138	132	128	135	**61**
135	131	139	135	131	139	135	131	139	133	129	137	**62**
137	133	141	137	133	141	137	133	141	135	131	138	**63**
138	134	142	138	134	142	138	134	142	136	132	140	**64**
140	136	144	140	136	144	140	136	144	138	134	141	**65**
142	138	146	142	138	146	142	138	146	139	135	143	**66**
143	139	147	143	139	147	143	139	147	141	137	144	**67**
145	141	149	145	141	149	145	141	149	142	138	146	**68**
146	142	150	146	142	150	146	142	150	144	140	147	**69**
148	144	152	148	144	152	148	144	152	145	141	149	**70**
150	146	154	150	146	154	150	146	154	147	143	150	**71**
151	147	155	151	147	155	151	147	155	148	144	152	**72**
153	149	157	153	149	157	153	149	157	150	146	153	**73**
154	150	158	154	150	158	154	150	158	151	147	155	**74**
156	152	160	156	152	160	156	152	160	153	149	156	**75**
158	154	162	158	154	162	158	154	162	154	150	158	**76**

Note. VC = Vocabulary, BD = Block Design, MR = Matrix reasoning, DS = Digit span, IN = Information, VP = Visual puzzles, PC = Picture completion, LN = Letter-number sequencing, [1-8]four-subtest combination numbers C23, C7, C19, C10, C16, C20, C12, and C5 in the derivation process, respectively (also numbered to correspond Supplemental Table 2).

Table 3.5. Estimated WAIS-IV Full Scale IQs and 95% confidence intervals for Sum of Scaled Scored for the Best 5-Subtest Short Forms

Table 5. Estimated WAIS-IV Full Scale IQs and 95% confidence intervals for Sum of Scaled Scored for the Best 5-Subtest Short Forms

	VC + IN + VP + DS + SS[1]			VC + IN + MR + DS + SS[2]			VC + IN + BD + MR + LN[3]		
	Reliable range = 2 *Unusual range = 8*			*Reliable range = 2* *Unusual range = 9*			*Reliable range = 2* *Unusual range = 9*		
Sum of scaled scores	**est. IQ**	**95% CI lower**	**95% CI upper**	**est. IQ**	**95% CI lower**	**95% CI upper**	**est. IQ**	**95% CI lower**	**95% CI upper**
5	42	38	45	42	38	45	42	38	45
6	43	39	47	43	39	47	43	39	47
7	44	40	48	44	40	48	44	40	48
8	45	41	49	45	41	49	45	41	49
9	47	43	51	47	43	51	47	43	51
10	48	44	52	48	44	52	48	44	52
11	49	45	53	49	45	53	49	45	53
12	51	47	55	51	47	55	51	47	55
13	52	48	56	52	48	56	52	48	56
14	53	49	57	53	49	57	53	49	57
15	55	51	58	55	51	58	55	51	58
16	56	52	60	56	52	60	56	52	60
17	57	53	61	57	53	61	57	53	61
18	58	54	62	58	54	62	58	54	62
19	60	56	64	60	56	64	60	56	64
20	61	57	65	61	57	65	61	57	65
21	62	58	66	62	58	66	62	58	66
22	64	60	68	64	60	68	64	60	68
23	65	61	69	65	61	69	65	61	69
24	66	62	70	66	62	70	66	62	70
25	68	64	71	68	64	71	68	64	71
26	69	65	73	69	65	73	69	65	73
27	70	66	74	70	66	74	70	66	74
28	71	67	75	71	67	75	71	67	75
29	73	69	77	73	69	77	73	69	77
30	74	70	78	74	70	78	74	70	78
31	75	71	79	75	71	79	75	71	79
32	77	73	81	77	73	81	77	73	81
33	78	74	82	78	74	82	78	74	82
34	79	75	83	79	75	83	79	75	83
35	81	77	84	81	77	84	81	77	84
36	82	78	86	82	78	86	82	78	86
37	83	79	87	83	79	87	83	79	87
38	84	80	88	84	80	88	84	80	88
39	86	82	90	86	82	90	86	82	90
40	87	83	91	87	83	91	87	83	91
41	88	84	92	88	84	92	88	84	92
42	90	86	94	90	86	94	90	86	94
43	91	87	95	91	87	95	91	87	95
44	92	88	96	92	88	96	92	88	96
45	94	90	97	94	90	97	94	90	97
46	95	91	99	95	91	99	95	91	99
47	96	92	100	96	92	100	96	92	100
48	97	93	101	97	93	101	97	93	101
49	99	95	103	99	95	103	99	95	103
50	100	96	104	100	96	104	100	96	104
51	101	97	105	101	97	105	101	97	105
52	103	99	107	103	99	107	103	99	107

53	104	100	108	104	100	108	104	100	108
54	105	101	109	105	101	109	105	101	109
55	107	103	110	107	103	110	107	103	110
56	108	104	112	108	104	112	108	104	112
57	109	105	113	109	105	113	109	105	113
58	110	106	114	110	106	114	110	106	114
59	112	108	116	112	108	116	112	108	116
60	113	109	117	113	109	117	113	109	117
61	114	110	118	114	110	118	114	110	118
62	116	112	120	116	112	120	116	112	120
63	117	113	121	117	113	121	117	113	121
64	118	114	122	118	114	122	118	114	122
65	120	116	123	120	116	123	120	116	123
66	121	117	125	121	117	125	121	117	125
67	122	118	126	122	118	126	122	118	126
68	123	119	127	123	119	127	123	119	127
69	125	121	129	125	121	129	125	121	129
70	126	122	130	126	122	130	126	122	130
71	127	123	131	127	123	131	127	123	131
72	129	125	133	129	125	133	129	125	133
73	130	126	134	130	126	134	130	126	134
74	131	127	135	131	127	135	131	127	135
75	133	129	136	133	129	136	133	129	136
76	134	130	138	134	130	138	134	130	138
77	135	131	139	135	131	139	135	131	139
78	136	132	140	136	132	140	136	132	140
79	138	134	142	138	134	142	138	134	142
80	139	135	143	139	135	143	139	135	143
81	140	136	144	140	136	144	140	136	144
82	142	138	146	142	138	146	142	138	146
83	143	139	147	143	139	147	143	139	147
84	144	140	148	144	140	148	144	140	148
85	146	142	149	146	142	149	146	142	149
86	147	143	151	147	143	151	147	143	151
87	148	144	152	148	144	152	148	144	152
88	149	145	153	149	145	153	149	145	153
89	151	147	155	151	147	155	151	147	155
90	152	148	156	152	148	156	152	148	156
91	153	149	157	153	149	157	153	149	157
92	155	151	159	155	151	159	155	151	159
93	156	152	160	156	152	160	156	152	160
94	157	153	161	157	153	161	157	153	161

Table 5 cont. Estimated WAIS-IV Full Scale IQs and 95% confidence intervals for Sum of Scaled Scored for the Best 5-Subtest Short Forms

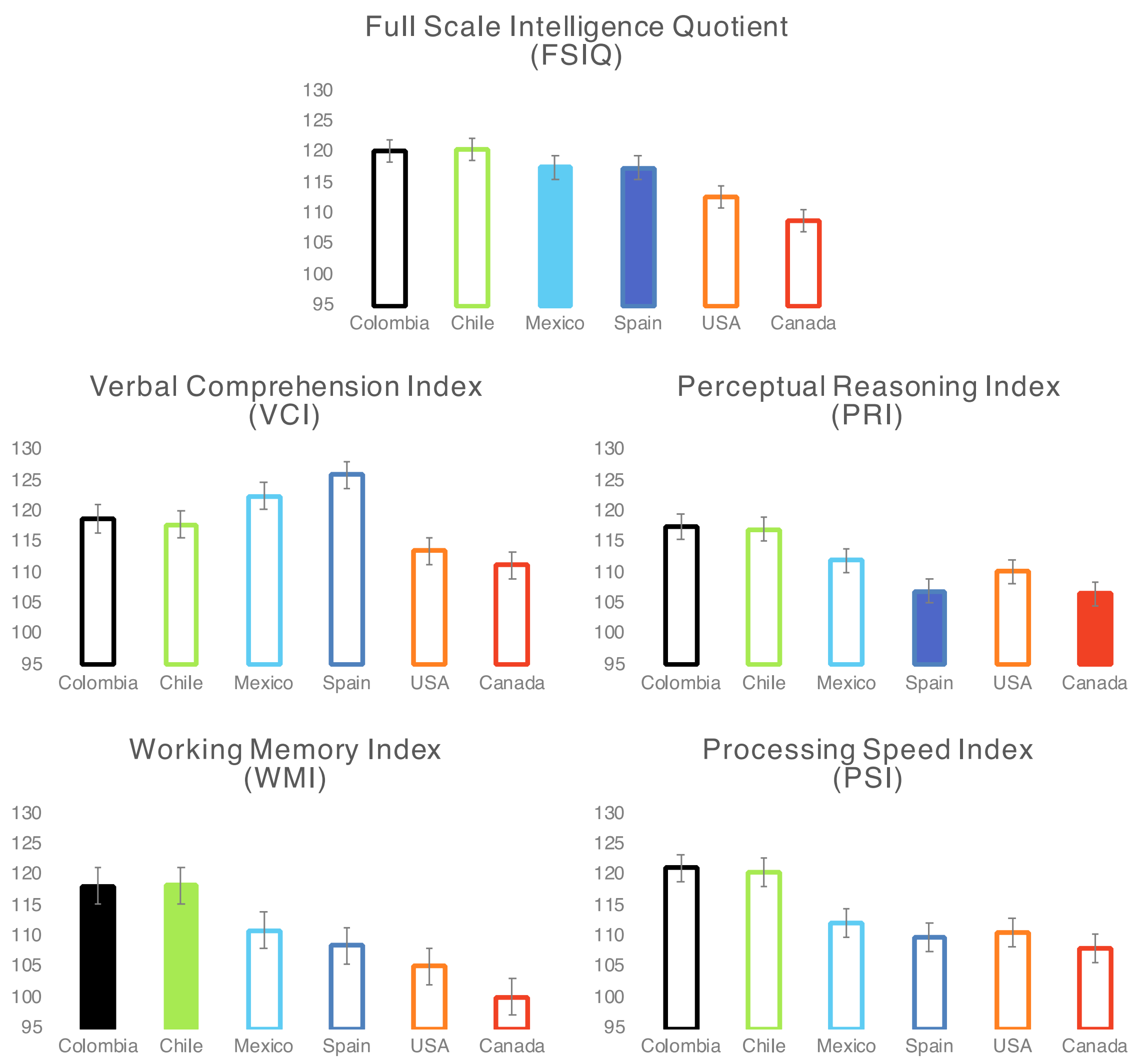
SI + VC + MR + PC + DS[4]			VC + IN + MR + PC + DS[5]			VC + IN + MR + PC + LN[6]			
Reliable range = 2 *Unusual range = 8*			*Reliable range = 2* *Unusual range = 9*			*Reliable range = 2* *Unusual range = 9*			
est. IQ	95% CI lower	95% CI upper	est. IQ	95% CI lower	95% CI upper	est. IQ	95% CI lower	95% CI upper	Sum of scaled scores
42	38	45	42	38	45	42	38	45	**5**
43	39	47	43	39	47	43	39	47	**6**
44	40	48	44	40	48	44	40	48	**7**
45	41	49	45	41	49	45	41	49	**8**
47	43	51	47	43	51	47	43	51	**9**
48	44	52	48	44	52	48	44	52	**10**
49	45	53	49	45	53	49	45	53	**11**
51	47	55	51	47	55	51	47	55	**12**
52	48	56	52	48	56	52	48	56	**13**
53	49	57	53	49	57	53	49	57	**14**
55	51	58	55	51	58	55	51	58	**15**
56	52	60	56	52	60	56	52	60	**16**
57	53	61	57	53	61	57	53	61	**17**
58	54	62	58	54	62	58	54	62	**18**
60	56	64	60	56	64	60	56	64	**19**
61	57	65	61	57	65	61	57	65	**20**
62	58	66	62	58	66	62	58	66	**21**
64	60	68	64	60	68	64	60	68	**22**
65	61	69	65	61	69	65	61	69	**23**
66	62	70	66	62	70	66	62	70	**24**
68	64	71	68	64	71	68	64	71	**25**
69	65	73	69	65	73	69	65	73	**26**
70	66	74	70	66	74	70	66	74	**27**
71	67	75	71	67	75	71	67	75	**28**
73	69	77	73	69	77	73	69	77	**29**
74	70	78	74	70	78	74	70	78	**30**
75	71	79	75	71	79	75	71	79	**31**
77	73	81	77	73	81	77	73	81	**32**
78	74	82	78	74	82	78	74	82	**33**
79	75	83	79	75	83	79	75	83	**34**
81	77	84	81	77	84	81	77	84	**35**
82	78	86	82	78	86	82	78	86	**36**
83	79	87	83	79	87	83	79	87	**37**
84	80	88	84	80	88	84	80	88	**38**
86	82	90	86	82	90	86	82	90	**39**
87	83	91	87	83	91	87	83	91	**40**
88	84	92	88	84	92	88	84	92	**41**
90	86	94	90	86	94	90	86	94	**42**
91	87	95	91	87	95	91	87	95	**43**
92	88	96	92	88	96	92	88	96	**44**
94	90	97	94	90	97	94	90	97	**45**
95	91	99	95	91	99	95	91	99	**46**
96	92	100	96	92	100	96	92	100	**47**
97	93	101	97	93	101	97	93	101	**48**
99	95	103	99	95	103	99	95	103	**49**
100	96	104	100	96	104	100	96	104	**50**
101	97	105	101	97	105	101	97	105	**51**
103	99	107	103	99	107	103	99	107	**52**

104	100	108	104	100	108	104	100	108	**53**
105	101	109	105	101	109	105	101	109	**54**
107	103	110	107	103	110	107	103	110	**55**
108	104	112	108	104	112	108	104	112	**56**
109	105	113	109	105	113	109	105	113	**57**
110	106	114	110	106	114	110	106	114	**58**
112	108	116	112	108	116	112	108	116	**59**
113	109	117	113	109	117	113	109	117	**60**
114	110	118	114	110	118	114	110	118	**61**
116	112	120	116	112	120	116	112	120	**62**
117	113	121	117	113	121	117	113	121	**63**
118	114	122	118	114	122	118	114	122	**64**
120	116	123	120	116	123	120	116	123	**65**
121	117	125	121	117	125	121	117	125	**66**
122	118	126	122	118	126	122	118	126	**67**
123	119	127	123	119	127	123	119	127	**68**
125	121	129	125	121	129	125	121	129	**69**
126	122	130	126	122	130	126	122	130	**70**
127	123	131	127	123	131	127	123	131	**71**
129	125	133	129	125	133	129	125	133	**72**
130	126	134	130	126	134	130	126	134	**73**
131	127	135	131	127	135	131	127	135	**74**
133	129	136	133	129	136	133	129	136	**75**
134	130	138	134	130	138	134	130	138	**76**
135	131	139	135	131	139	135	131	139	**77**
136	132	140	136	132	140	136	132	140	**78**
138	134	142	138	134	142	138	134	142	**79**
139	135	143	139	135	143	139	135	143	**80**
140	136	144	140	136	144	140	136	144	**81**
142	138	146	142	138	146	142	138	146	**82**
143	139	147	143	139	147	143	139	147	**83**
144	140	148	144	140	148	144	140	148	**84**
146	142	149	146	142	149	146	142	149	**85**
147	143	151	147	143	151	147	143	151	**86**
148	144	152	148	144	152	148	144	152	**87**
149	145	153	149	145	153	149	145	153	**88**
151	147	155	151	147	155	151	147	155	**89**
152	148	156	152	148	156	152	148	156	**90**
153	149	157	153	149	157	153	149	157	**91**
155	151	159	155	151	159	155	151	159	**92**
156	152	160	156	152	160	156	152	160	**93**
157	153	161	157	153	161	157	153	161	**94**

Note. VC = Vocabulary, BD = Block Design, MR = Matrix reasoning, DS = Digit span, IN = Information, VP = Visual puzzles, PC = Picture completion, LN = Letter-number sequencing, [1-6]five-subtest combination numbers C21, C12, C14, C23, C4, and C8 in the derivation process, respectively (also numbered to correspond Supplemental Table 2).

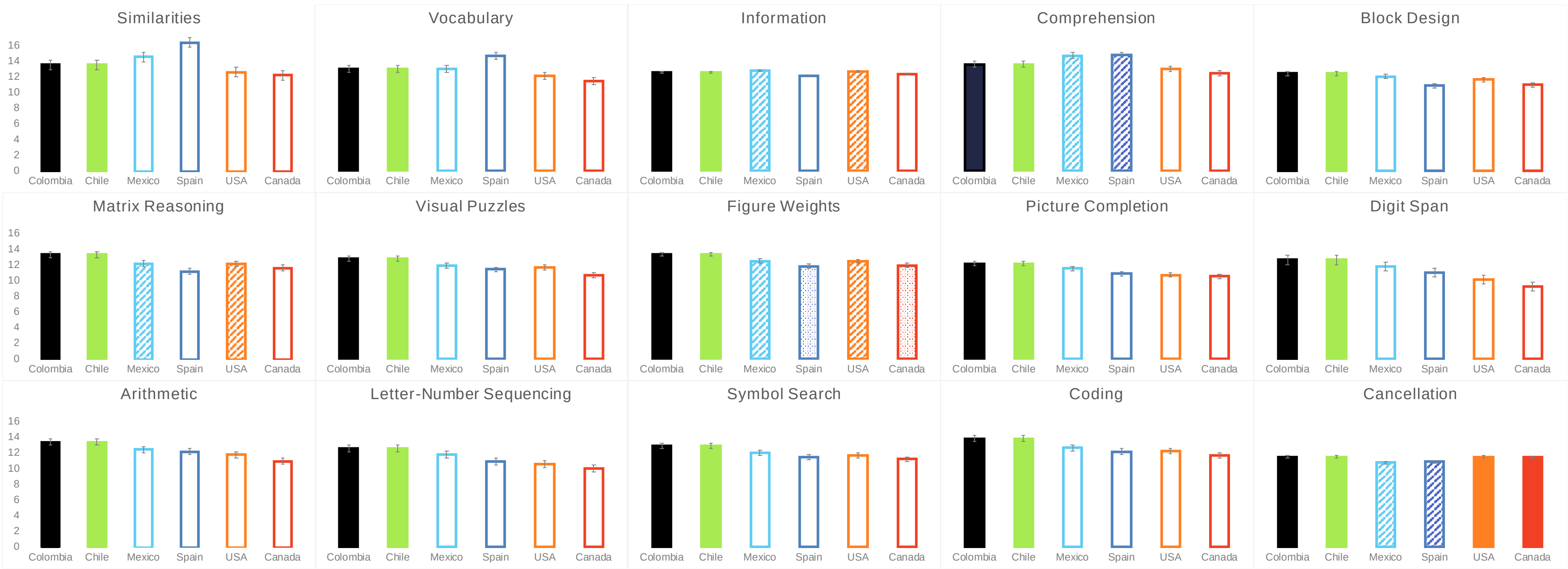
Figures

Figure 1.1. Mean WAIS-IV Full Scale Intelligence Quotient and Index scores when scored with each of the selected six country norms



Note. Data available in Table 5 and Supplemental Table 2. Error bars indicated standard error. Differences at the $p < .05$ level. Filled bars indicate patterns of scores that do not differ from one another. Full Scale Intelligence Quotient (FSIQ): all comparisons different except Mexico versus Spain. Verbal Comprehension Index (VCI): all comparisons different. Performance Reasoning Index (PRI): all comparisons different except Spain versus Canada. Working Memory Index (WMI): All comparisons different except Colombia versus Chile. Processing Speed Index (PSI): All comparisons different.

Figure 1.2. Mean WAIS-IV subtest scaled scores when scored with each of the selected six country norms



Note. Data available in Table 5 and Supplemental Table 2. Error bars indicated standard error. Differences at the $p < .05$ level. Filled bars indicate patterns of scores that do not differ from one another. Similarities: all comparisons different except Colombia versus Chile. Vocabulary: all comparisons different except Colombia versus Chile versus Mexico. Information: all comparisons different except Colombia versus Chile and Mexico versus United States. Comprehension: all comparisons different except Colombia versus Chile and Mexico versus Spain. Block Design: all comparisons different except Colombia versus Chile. Matrix Reasoning: all comparisons different except Colombia versus Chile and Mexico versus United States. Visual Puzzles: all comparisons different except Colombia versus Chile. Figure Weights: all comparisons different except Colombia versus Chile, Mexico versus United States, and Spain versus Canada. Picture Completion: all comparisons different except Colombia versus Chile. Digit Span: all comparisons different except Colombia versus Chile. Arithmetic: all comparisons different except Colombia versus Chile. Letter-Number Sequencing: all comparisons different except Colombia versus Chile. Symbol Search: all comparisons different except Colombia versus Chile. Coding: all comparisons different except Colombia versus Chile. Cancellation: no differences between Colombia, Chile, United States, and Canada, and no differences between Mexico and Spain.

Figure 1.3. Percentage of individuals within each clinical classification for the Full-Scale Intelligence Quotient (FSIQ) when scored with each of the selected six country norms

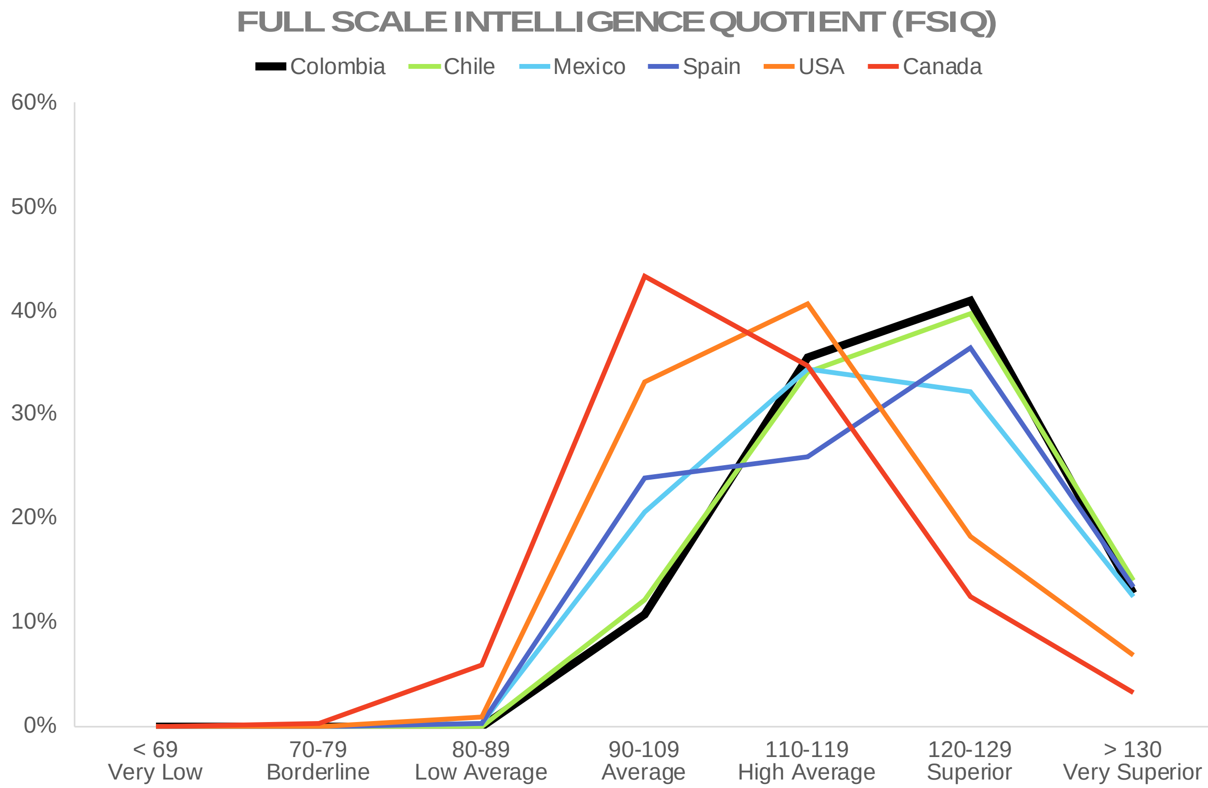


Figure 1.4. Percentage of individuals within each clinical classification for the Wechsler Adult Intelligence Scale – Fourth Edition (WAIS-IV) indexes when scored with each of the selected six country norms.

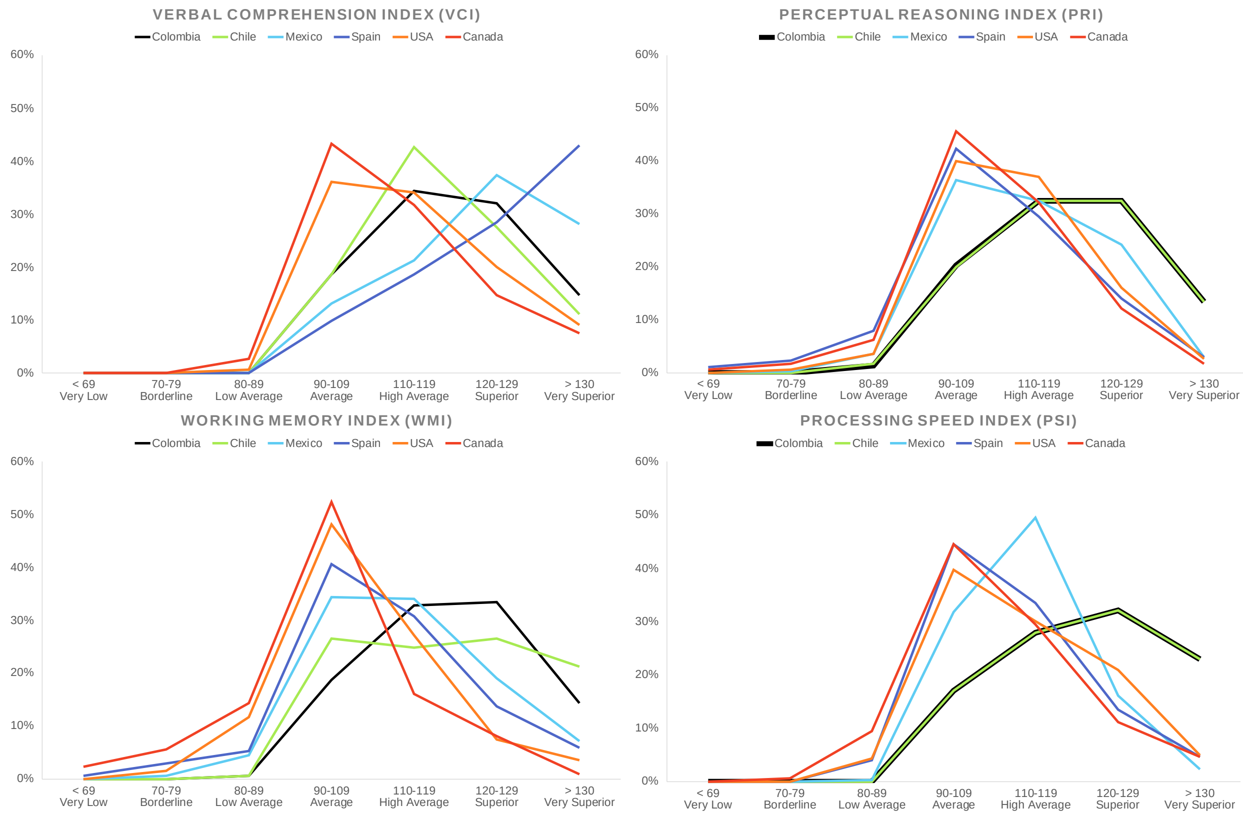
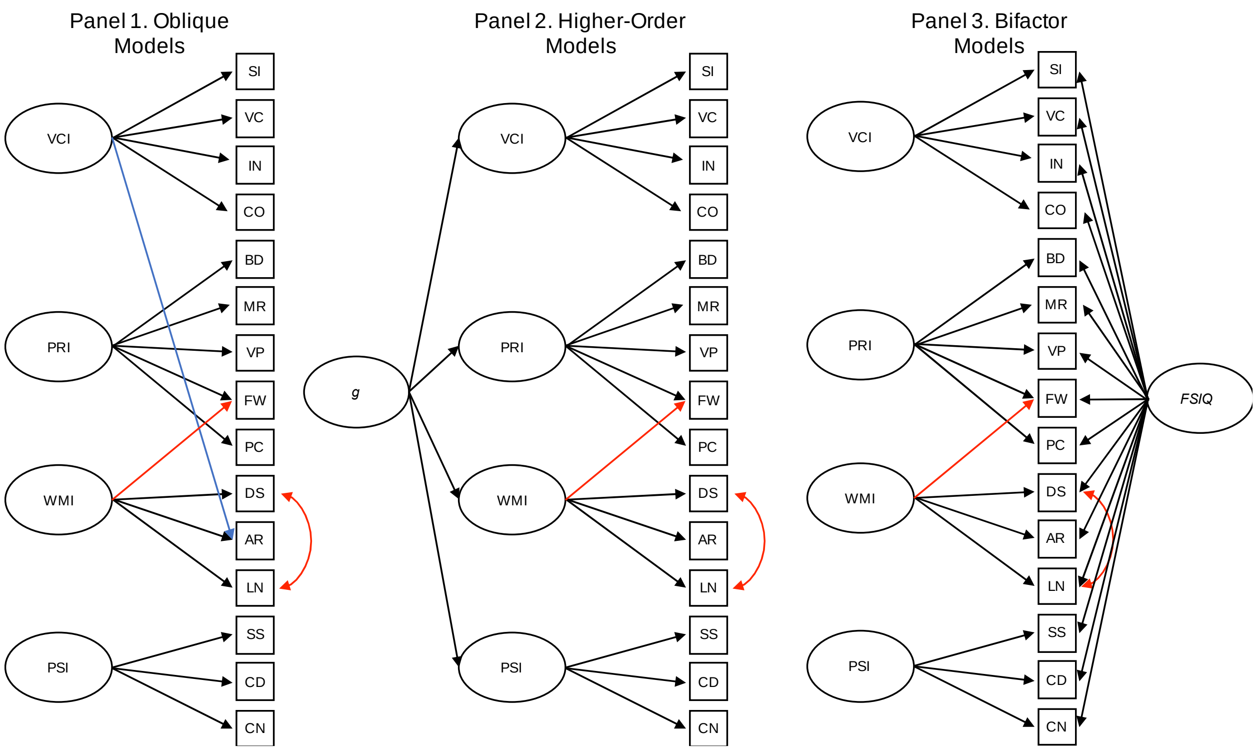
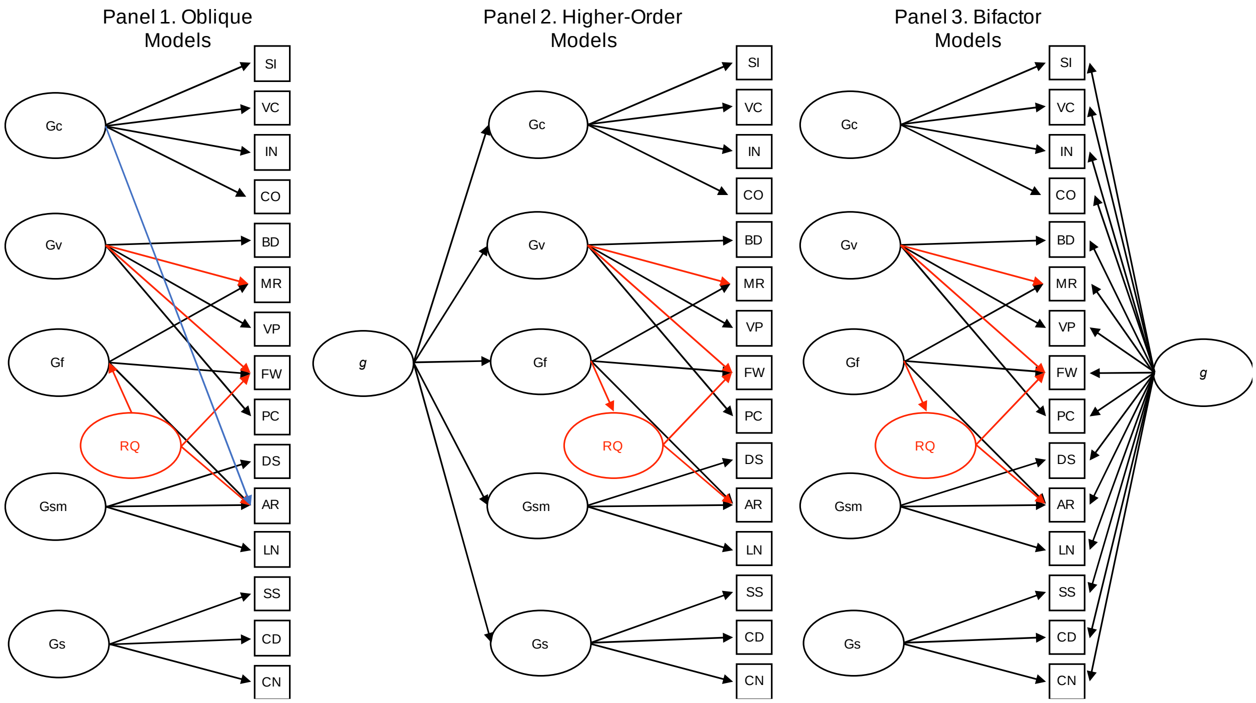


Figure 2.1. Four-factor (Wechsler) models and their variants



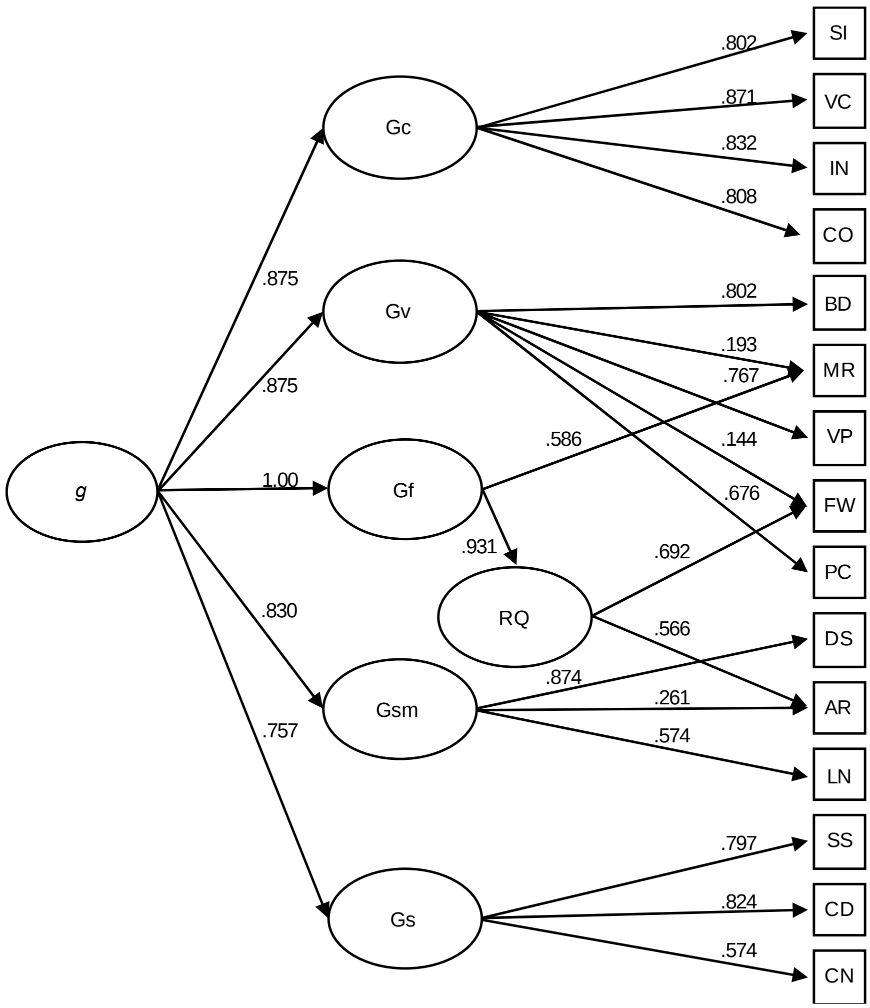
Note. Four-factor models tested in their oblique (panel 1) higher-order (panel 2) and bifactor (panel 3) variants. Black lines show the base model (Model A). Colored lines show model variants as specified in Table 2 (red lines = Models B and C, blue + red lines = Model D and E). Due to negative factor loading of AR on VCI (blue line panel 1), these variants are not reported in higher-order and bifactor models. SI = Similarities, VC = Vocabulary, IN = Information, CO = Comprehension, BD = Block Design, MR = Matrix Reasoning, VP = Visual Puzzles, FW = Figure Weights, PC = Picture Completion, DS = Digit Span, AR = Arithmetic, LN = Letter-Number Sequencing, SS = Symbol Search, CD = Coding, CA = Cancellation, VCI = Verbal Comprehension Index, PRI = Performance Reasoning Index, WMI = Working Memory Index, PSI = Processing Speed Index, FSIQ = Full-Scale Intelligence Quotient.

Figure 2.2. Five-factor (CHC) models and their variants



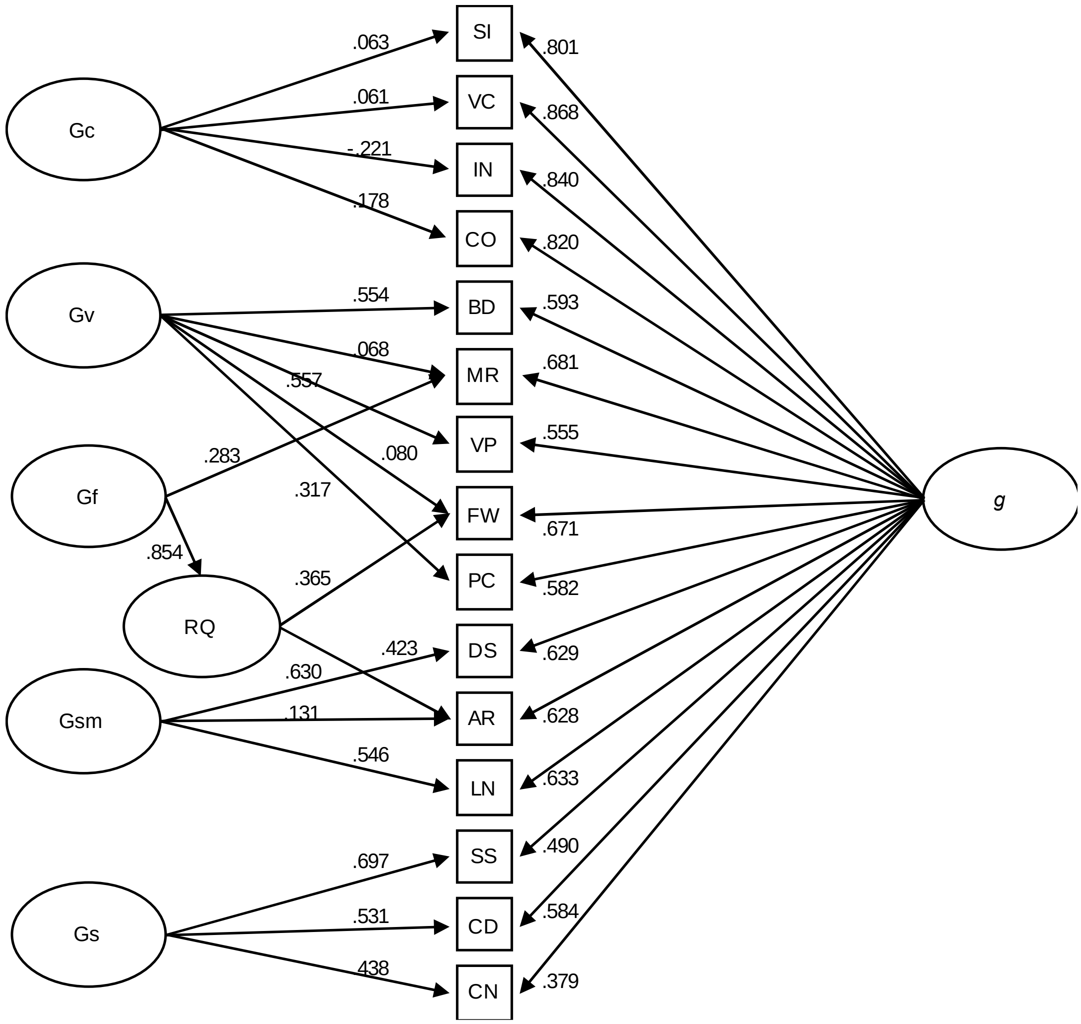
Note. Five-factor models tested in their oblique (panel 1) higher-order (panel 2) and bifactor (panel 3) variants. Oblique models are detailed in Table 2. Black lines show Model A with its variant Model B (addition of blue line). Black + red lines show Model C with its variant Model D (addition of blue line). Due to negative factor loading of AR on VCI (blue line), these variants are not reported in higher-order and bifactor models. SI = Similarities, VC = Vocabulary, IN = Information, CO = Comprehension, BD = Block Design, MR = Matrix Reasoning, VP = Visual Puzzles, FW = Figure Weights, PC = Picture Completion, DS = Digit Span, AR = Arithmetic, LN = Letter-Number Sequencing, SS = Symbol Search, CD = Coding, CA = Cancellation, Gc = crystalized intelligence, Gf = fluid intelligence, Gv = visual processing, Gsm = short-term memory, Gs = processing speed, RQ = Quantitative Reasoning.

Figure 2.3. Best fitting higher-order model



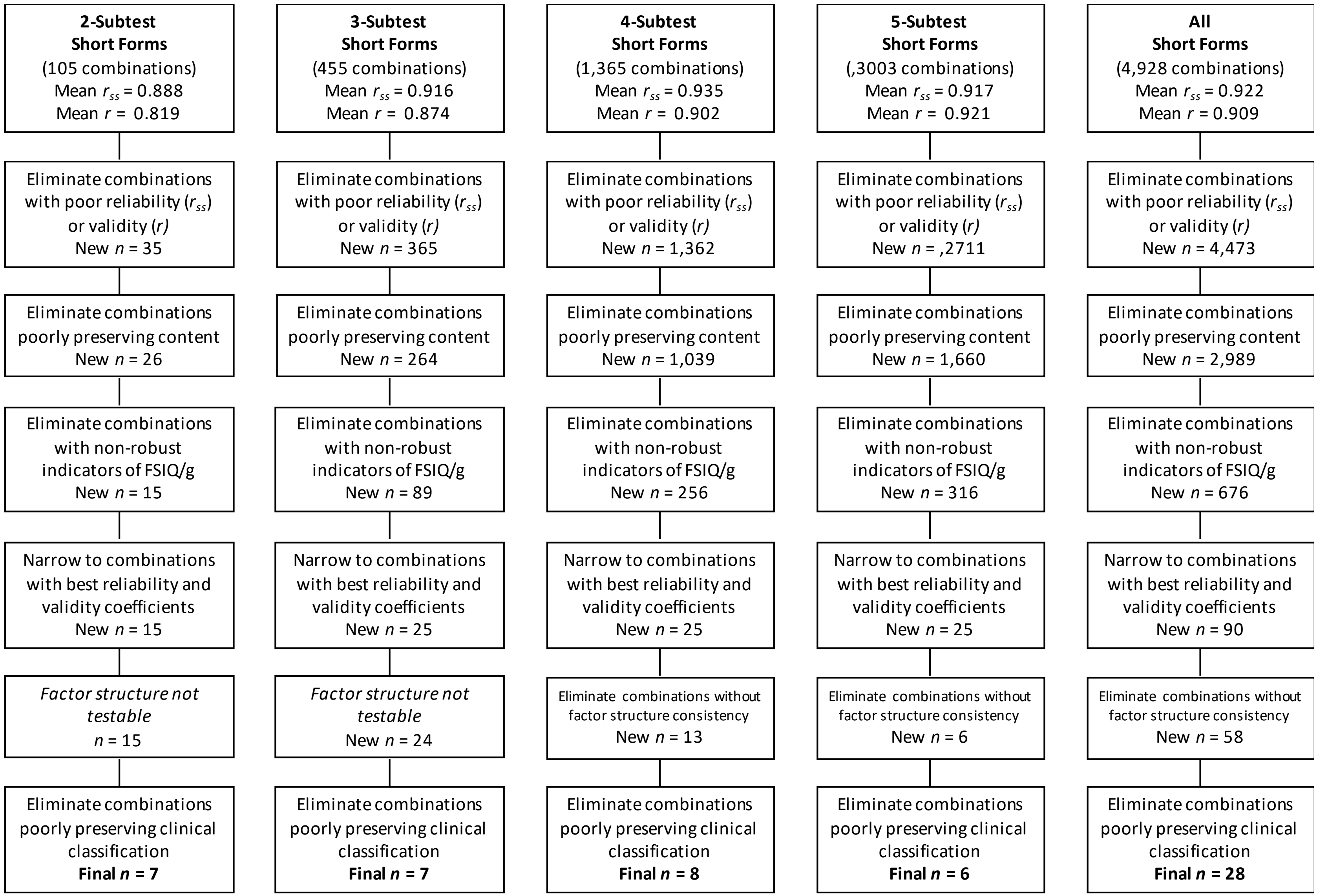
Note. Standardized estimates and fit statistics for best fitting higher-order model (five-factor model C, Table 3, Model 17): χ^2 = 181.89, df = 82, root mean square error of approximation = 0.043, standardized root mean square residual = 0.027, comparative fit index = 0.984, Tucker-Lewis index = 0.979, Akaike information criterion = 45268.05, Bayesian information criterion = 45507.10, adjusted Bayesian information criterion = 45338.82. SI = Similarities, VC = Vocabulary, IN = Information, CO = Comprehension, BD = Block Design, MR = Matrix Reasoning, VP = Visual Puzzles, FW = Figure Weights, PC = Picture Completion, DS = Digit Span, AR = Arithmetic, LN = Letter-Number Sequencing, SS = Symbol Search, CD = Coding, CA = Cancellation, Gc = crystalized intelligence, Gf = fluid intelligence, Gv = visual processing, Gsm = short-term memory, Gs = processing speed, RQ = Quantitative Reasoning.

Figure 2.4. Best fitting bifactor model



Note. Standardized estimates and fit statistics for best fitting bifactor model (five-factor model C, Table 3, Model 26): χ^2= 87.90, *df* = 62, root mean square error of approximation = 0.025, standardized root mean square residual = 0.016, comparative fit index = 0.996, Tucker-Lewis index = 0.993, Akaike information criterion = 45214.06, Bayesian information criterion = 45543.31, adjusted Bayesian information criterion = 45311.53. SI = Similarities, VC = Vocabulary, IN = Information, CO = Comprehension, BD = Block Design, MR = Matrix Reasoning, VP = Visual Puzzles, FW = Figure Weights, PC = Picture Completion, DS = Digit Span, AR = Arithmetic, LN = Letter-Number Sequencing, SS = Symbol Search, CD = Coding, CA = Cancellation, Gc = crystalized intelligence, Gf = fluid intelligence, Gv = visual processing, Gsm = short-term memory, Gs = processing speed, RQ = Quantitative Reasoning.

Figure 3.1. Flow Chart of the Chilean WAIS-IV Derivation Process



Supplementary Materials

Supplemental Table 1.1. Omnibus testing for differences when applying Colombian, Chilean, Mexican, Spanish, American, or Canadian WAIS-IV norms to the present sample of 305 Colombian executives

	ANOVA				Mauchly's Test of Sphericity			Multivariate Tests				
	F	*df**	*p*	η^2	χ^2	*p*	ε^*	*V*	F	*df*	*p*	η^2
Full-Scale Intelligence Quotient (FSIQ)	913.58	2.189, 665.357	<0.0005	0.750	1262.839	<0.0005	0.438	0.966	1706.41	5, 300	<0.0005	0.966
Verbal Comprehension Index (VCI)	1176.16	2.608, 792.687	<0.0005	0.795	1499.861	<0.0005	0.522	0.953	1220.36	5, 300	<0.0005	0.953
Perceptual Reasoning Index (PRI)	866.38	2.001, 608.318	<0.0005	0.740	1739.941	<0.0005	0.400	0.915	648.86	5, 300	<0.0005	0.915
Working Memory Index (WMI)	3374.86	2.527, 768.100	<0.0005	0.917	1068.135	<0.0005	0.505	0.973	2203.84	5, 300	<0.0005	0.973
Processing Speed Index (PSI)	1495.76	3.118, 947.812	<0.0005	0.831	1170.890	<0.0005	0.624	0.965	1640.94	5, 300	<0.0005	0.965
Verbal Comprehension Subtests	F	*df*	*p*	η^2	χ^2	*p*	ε^*	*V*	F	*df*	*p*	η^2
Similarities	1647.27	5, 1520	<0.0005	0.844	--	--	0.528	0.954	1565.46	4, 301	<0.0005	0.954
Vocabulary	1055.29	5, 1520	<0.0005	0.776	--	--	0.482	0.943	1246.64	4, 301	<0.0005	0.943
Information	78.35	5, 1520	<0.0005	0.205	--	--	0.527	0.613	119.02	4, 301	<0.0005	0.613
Comprehension	960.40	5, 1520	<0.0005	0.760	--	--	0.594	0.919	853.03	4, 301	<0.0005	0.919
Perceptual Reasoning Subtests												
Block Design	464.93	5, 1520	<0.0005	0.605	--	--	0.410	0.863	474.73	4, 301	<0.0005	0.863
Matrix Reasoning	756.16	5, 1520	<0.0005	0.713	--	--	0.500	0.902	690.28	4, 301	<0.0005	0.902
Visual Puzzles	493.54	5, 1520	<0.0005	0.619	--	--	0.484	0.888	598.90	4, 301	<0.0005	0.888
Figure Weights	438.80	5, 1520	<0.0005	0.591	--	--	0.529	0.889	603.95	4, 301	<0.0005	0.889
Picture Completion	584.40	5, 1520	<0.0005	0.658			0.646	0.871	509.59	4, 301	<0.0005	0.871
Working Memory Subtests												
Digit Span	2872.37	5, 1520	<0.0005	0.904	--	--	0.532	0.967	2237.53	4, 301	<0.0005	0.967
Arithmetic	1357.51	5, 1520	<0.0005	0.817	--	--	0.537	0.940	1176.60	4, 301	<0.0005	0.940
Letter-Number Sequencing	683.11	5, 1520	<0.0005	0.692	--	--	0.487	0.864	477.30	4, 301	<0.0005	0.864
Processing Speed Subtests												
Symbol Search	555.57	5, 1520	<0.0005	0.646	--	--	0.530	0.899	673.34	4, 301	<0.0005	0.899
Coding	866.17	5, 1520	<0.0005	0.740	--	--	0.593	0.919	848.72	4, 301	<0.0005	0.919
Cancellation	106.42	5, 1520	<0.0005	0.259	--	--	0.439	0.663	148.00	4, 301	<0.0005	0.663

*Values reported using the Greenhouse-Geisser corretions due to violation of sphericity. -- Indicates values that cannot be computed on the subtest level.

Supplemental Table 2.1. Demographic Statistics for the Chilean WAIS-IV Ages 16-69 (N=672)

Supplemental Table 2. Post-hoc comparisons for WAIS-IV Full Scale Intelligence Quotient (FSIQ), Indexes, and Subtests

	Mean Difference	95% Confidence Interval for Difference	Significance	Standard Error
Full Scale Intelligence Quotient (FSIQ)				
Colombia versus Chile	0.29	(0.09, 0.48)	<0.0005	0.067
Colombia versus Mexico	-2.70	(-3.26, -2.13)	<0.0005	0.190
Colombia versus Spain	-2.74	(-3.62, -1.86)	<0.0005	0.298
Colombia versus USA	-7.57	(-8.36, -6.77)	<0.0005	0.269
Colombia versus Canada	-11.43	(-12.20, -10.66)	<0.0005	0.260
Chile versus Mexico	-2.98	(-3.52, -2.43)	<0.0005	0.186
Chile versus Spain	-3.02	(-3.85, -2.20)	<0.0005	0.278
Chile versus USA	-7.85	(-8.63, -7.08)	<0.0005	0.261
Chile versus Canada	-11.72	(-12.42, -11.02)	<0.0005	0.237
Mexico versus Spain	-0.04	(-0.61, 0.53)	1.000	0.192
Mexico versus USA	-4.87	(-5.33, -4.41)	<0.0005	0.155
Mexico versus Canada	-8.74	(-9.15, -8.33)	<0.0005	0.138
Spain versus USA	-4.83	(-5.56, -4.10)	<0.0005	0.248
Spain versus Canada	-8.70	(-9.19, -8.20)	<0.0005	0.168
USA versus Canada	-3.87	(-4.26, -3.47)	<0.0005	0.135
Verbal Comprehension Index (VCI)				
Colombia versus Chile	-0.95	(-1.03, -0.87)	<0.0005	0.028
Colombia versus Mexico	3.65	(2.92, 4.38)	<0.0005	0.248
Colombia versus Spain	7.18	(6.42, 7.93)	<0.0005	0.255
Colombia versus USA	-5.23	(-6.05, -4.41)	<0.0005	0.277
Colombia versus Canada	-7.62	(-8.29, -6.95)	<0.0005	0.227
Chile versus Mexico	4.60	(3.85, 5.35)	<0.0005	0.252
Chile versus Spain	8.13	(7.36, 8.89)	<0.0005	0.258
Chile versus USA	-4.28	(-5.10, -3.46)	<0.0005	0.277
Chile versus Canada	-6.67	(-7.33, -6.01)	<0.0005	0.223
Mexico versus Spain	3.53	(3.04, 4.01)	<0.0005	0.163
Mexico versus USA	-8.88	(-9.56, -8.21)	<0.0005	0.228
Mexico versus Canada	-11.27	(-11.79, -10.75)	<0.0005	0.175
Spain versus USA	-12.41	(-13.22, -11.59)	<0.0005	0.276
Spain versus Canada	-14.80	(-15.42, -14.18)	<0.0005	0.210
USA versus Canada	-2.39	(-2.84, -1.94)	<0.0005	0.151
Perceptual Reasoning Index (PRI)				
Colombia versus Chile	-0.48	(-0.57, -0.39)	<0.0005	0.031
Colombia versus Mexico	-5.43	(-6.00, -4.86)	<0.0005	0.192
Colombia versus Spain	-10.56	(-11.62, -9.50)	<0.0005	0.358
Colombia versus USA	-7.26	(-7.93, -6.60)	<0.0005	0.225
Colombia versus Canada	-10.97	(-11.64, -10.31)	<0.0005	0.224
Chile versus Mexico	-4.95	(-5.52, -4.38)	<0.0005	0.193
Chile versus Spain	-10.08	(-11.12, -9.03)	<0.0005	0.353
Chile versus USA	-6.78	(-7.45, -6.11)	<0.0005	0.225
Chile versus Canada	-10.49	(-11.14, -9.84)	<0.0005	0.220
Mexico versus Spain	-5.13	(-5.93, -4.32)	<0.0005	0.272
Mexico versus USA	-1.83	(-2.20, -1.46)	<0.0005	0.124

	Mean Difference	95% Confidence Interval for Difference	Significance	Standard Error
Mexico versus Canada	-5.54	(-5.91, -5.17)	<0.0005	0.124
Spain versus USA	3.30	(2.43, 4.17)	<0.0005	0.293
Spain versus Canada	-0.41	(-1.10, 0.28)	1.0000	0.233
USA versus Canada	-3.71	(-4.06, -3.36)	<0.0005	0.118
Working Memory Index (WMI)				
Colombia versus Chile	0.05	(-0.07, 0.16)	1.0000	0.040
Colombia versus Mexico	-7.23	(-7.57, -6.89)	<0.0005	0.115
Colombia versus Spain	-9.80	(-10.48, -9.11)	<0.0005	0.232
Colombia versus USA	-13.08	(-13.69, -12.48)	<0.0005	0.204
Colombia versus Canada	-18.11	(-18.70, -17.51)	<0.0005	0.201
Chile versus Mexico	-7.27	(-7.62, -6.93)	<0.0005	0.117
Chile versus Spain	-9.84	(-10.50, -9.19)	<0.0005	0.222
Chile versus USA	-13.13	(-13.72, -12.52)	<0.0005	0.199
Chile versus Canada	-18.15	(-18.72, -17.59)	<0.0005	0.191
Mexico versus Spain	-2.57	(-3.15, -1.99)	<0.0005	0.197
Mexico versus USA	-5.86	(-6.33, -5.39)	<0.0005	0.159
Mexico versus Canada	-10.88	(-11.38, -10.38)	<0.0005	0.170
Spain versus USA	-3.29	(-3.85, -2.72)	<0.0005	0.192
Spain versus Canada	-8.31	(-8.79, -7.82)	<0.0005	0.164
USA versus Canada	-5.02	(-5.40, -4.65)	<0.0005	0.128
Processig Speed Index (PSI)				
Colombia versus Chile	-0.68	(-0.79, -0.57)	<0.0005	0.036
Colombia versus Mexico	-8.84	(-9.48, -8.20)	<0.0005	0.217
Colombia versus Spain	-11.22	(-11.71, -10.72)	<0.0005	0.167
Colombia versus USA	-10.51	(-11.17, -9.85)	<0.0005	0.222
Colombia versus Canada	-13.01	(-13.61, -12.41)	<0.0005	0.204
Chile versus Mexico	-8.16	(-8.87, -7.45)	<0.0005	0.239
Chile versus Spain	-10.54	(-11.05, -10.02)	<0.0005	0.175
Chile versus USA	-9.83	(-10.50, -9.16)	<0.0005	0.227
Chile versus Canada	-12.33	(-12.94, -11.73)	<0.0005	0.205
Mexico versus Spain	-2.38	(-3.03, -1.72)	<0.0005	0.221
Mexico versus USA	-1.67	(-2.38, -0.96)	<0.0005	0.239
Mexico versus Canada	-4.17	(-4.98, -3.36)	<0.0005	0.275
Spain versus USA	0.71	(0.10, 1.32)	<0.0005	0.206
Spain versus Canada	-1.79	(-2.37, -1.22)	<0.0005	0.194
USA versus Canada	-2.50	(-2.94, -2.06)	<0.0005	0.150
Similarities				
Colombia versus Chile	0.00	(0.00, 0.00)	--	0.000
Colombia versus Mexico	1.00	(0.83, 1.16)	<0.0005	0.056
Colombia versus Spain	2.82	(2.62, 3.02)	<0.0005	0.067
Colombia versus USA	-0.96	(-1.14, -0.79)	<0.0005	0.060
Colombia versus Canada	-1.34	(-1.48, -1.20)	<0.0005	0.047
Chile versus Mexico	1.00	(0.83, 1.16)	<0.0005	0.056
Chile versus Spain	2.82	(2.62, 3.02)	<0.0005	0.067
Chile versus USA	-0.96	(-1.14, -0.79)	<0.0005	0.060
Chile versus Canada	-1.34	(-1.48, -1.20)	<0.0005	0.047

	Mean Difference	95% Confidence Interval for Difference	Significance	Standard Error
Mexico versus Spain	1.82	(1.67, 1.97)	<0.0005	0.051
Mexico versus USA	-1.96	(-2.08, -1.84)	<0.0005	0.039
Mexico versus Canada	-2.34	(-2.45, -2.22)	<0.0005	0.039
Spain versus USA	-3.78	(-3.98, -3.59)	<0.0005	0.066
Spain versus Canada	-4.16	(-4.33, -3.99)	<0.0005	0.057
USA versus Canada	-0.38	(-0.47, -0.28)	<0.0005	0.033
Vocabulary				
Colombia versus Chile	0.00	(0.00, 0.00)	--	0.000
Colombia versus Mexico	-0.01	(-0.11, 0.09)	1.0000	0.034
Colombia versus Spain	1.68	(1.51, 1.84)	<0.0005	0.056
Colombia versus USA	-0.91	(-1.08, -0.74)	<0.0005	0.057
Colombia versus Canada	-1.53	(-1.65, -1.41)	<0.0005	0.042
Chile versus Mexico	-0.01	(-0.11, 0.09)	1.0000	0.034
Chile versus Spain	1.68	(1.51, 1.84)	<0.0005	0.056
Chile versus USA	-0.91	(-1.08, -0.74)	<0.0005	0.057
Chile versus Canada	-1.53	(-1.65, -1.41)	<0.0005	0.042
Mexico versus Spain	1.69	(1.53, 1.85)	<0.0005	0.053
Mexico versus USA	-0.90	(-1.02, -0.78)	<0.0005	0.040
Mexico versus Canada	-1.52	(-1.61, -1.43)	<0.0005	0.031
Spain versus USA	-2.59	(-2.81, -2.37)	<0.0005	0.073
Spain versus Canada	-3.21	(-3.38, -3.04)	<0.0005	0.058
USA versus Canada	-0.62	(-0.71, -0.53)	<0.0005	0.030
Information				
Colombia versus Chile	0.00	(0.00, 0.00)	--	0.000
Colombia versus Mexico	0.27	(0.17, 0.37)	<0.0005	0.033
Colombia versus Spain	-0.47	(-0.63, -0.32)	<0.0005	0.052
Colombia versus USA	0.16	(0.02, 0.30)	<0.0005	0.047
Colombia versus Canada	-0.22	(-0.37, -0.08)	<0.0005	0.050
Chile versus Mexico	0.27	(0.17, 0.37)	<0.0005	0.033
Chile versus Spain	-0.47	(-0.63, -0.32)	<0.0005	0.052
Chile versus USA	0.16	(0.02, 0.30)	<0.0005	0.047
Chile versus Canada	-0.22	(-0.37, -0.08)	<0.0005	0.050
Mexico versus Spain	-0.74	(-0.87, -0.62)	<0.0005	0.043
Mexico versus USA	-0.11	(-0.25, 0.03)	0.3068	0.048
Mexico versus Canada	-0.50	(-0.63, -0.36)	<0.0005	0.047
Spain versus USA	0.63	(0.50, 0.76)	<0.0005	0.044
Spain versus Canada	0.25	(0.15, 0.35)	<0.0005	0.035
USA versus Canada	-0.38	(-0.49, -0.28)	<0.0005	0.034
Comprehension				
Colombia versus Chile	0.00	(0.00, 0.00)	--	0.000
Colombia versus Mexico	1.11	(1.00, 1.23)	<0.0005	0.039
Colombia versus Spain	1.18	(1.05, 1.31)	<0.0005	0.045
Colombia versus USA	-0.59	(-0.73, -0.44)	<0.0005	0.048
Colombia versus Canada	-1.14	(-1.28, -1.01)	<0.0005	0.047
Chile versus Mexico	1.11	(1.00, 1.23)	<0.0005	0.039
Chile versus Spain	1.18	(1.05, 1.31)	<0.0005	0.045

	Mean Difference	95% Confidence Interval for Difference	Significance	Standard Error
Chile versus USA	-0.59	(-0.73, -0.44)	<0.0005	0.048
Chile versus Canada	-1.14	(-1.28, -1.01)	<0.0005	0.047
Mexico versus Spain	0.07	(-0.04, 0.18)	0.9034	0.037
Mexico versus USA	-1.70	(-1.83, -1.56)	<0.0005	0.046
Mexico versus Canada	-2.26	(-2.39, -2.12)	<0.0005	0.046
Spain versus USA	-1.77	(-1.90, -1.63)	<0.0005	0.046
Spain versus Canada	-2.33	(-2.45, -2.20)	<0.0005	0.042
USA versus Canada	-0.56	(-0.64, -0.47)	<0.0005	0.030
Block Design				
Colombia versus Chile	0.00	(0.00, 0.00)	--	0.000
Colombia versus Mexico	-0.36	(-0.51, -0.22)	<0.0005	0.050
Colombia versus Spain	-1.52	(-1.70, -1.34)	<0.0005	0.061
Colombia versus USA	-0.77	(-0.92, -0.61)	<0.0005	0.053
Colombia versus Canada	-1.44	(-1.58, -1.29)	<0.0005	0.050
Chile versus Mexico	-0.36	(-0.51, -0.22)	<0.0005	0.050
Chile versus Spain	-1.52	(-1.70, -1.34)	<0.0005	0.061
Chile versus USA	-0.77	(-0.92, -0.61)	<0.0005	0.053
Chile versus Canada	-1.44	(-1.58, -1.29)	<0.0005	0.050
Mexico versus Spain	-1.15	(-1.27, -1.04)	<0.0005	0.038
Mexico versus USA	-0.40	(-0.49, -0.31)	<0.0005	0.031
Mexico versus Canada	-1.07	(-1.16, -0.99)	<0.0005	0.029
Spain versus USA	0.75	(0.63, 0.87)	<0.0005	0.041
Spain versus Canada	0.08	(-0.02, 0.18)	0.261	0.034
USA versus Canada	-0.67	(-0.76, -0.58)	<0.0005	0.029
Martix Reasoning				
Colombia versus Chile	0.00	(0.00, 0.00)	--	0.000
Colombia versus Mexico	-1.14	(-1.23, -1.06)	<0.0005	0.030
Colombia versus Spain	-2.14	(-2.33, -1.96)	<0.0005	0.063
Colombia versus USA	-1.16	(-1.27, -1.06)	<0.0005	0.034
Colombia versus Canada	-1.69	(-1.80, -1.57)	<0.0005	0.040
Chile versus Mexico	-1.14	(-1.23, 1.06)	<0.0005	0.030
Chile versus Spain	-2.14	(-2.33, -1.96)	<0.0005	0.063
Chile versus USA	-1.16	(-1.27, -1.06)	<0.0005	0.034
Chile versus Canada	-1.69	(-1.80, -1.57)	<0.0005	0.040
Mexico versus Spain	-1.00	(-1.17, -0.82)	<0.0005	0.060
Mexico versus USA	-0.02	(-0.14, 0.10)	1.0000	0.042
Mexico versus Canada	-0.54	(-0.67, -0.41)	<0.0005	0.044
Spain versus USA	0.98	(0.79, 1.16)	<0.0005	0.063
Spain versus Canada	0.46	(0.30, 0.61)	<0.0005	0.053
USA versus Canada	-0.52	(-0.61, -0.43)	<0.0005	0.031
Visual Puzzles				
Colombia versus Chile	0.00	(0.00, 0.00)	--	0.000
Colombia versus Mexico	-0.83	(-0.97, -0.70)	<0.0005	0.046
Colombia versus Spain	-1.35	(-1.56, -1.14)	<0.0005	0.072
Colombia versus USA	-1.09	(-1.26, -0.92)	<0.0005	0.058
Colombia versus Canada	-2.06	(-2.21, -1.92)	<0.0005	0.049

	Mean Difference	95% Confidence Interval for Difference	Significance	Standard Error
Chile versus Mexico	-0.83	(-0.97, -0.70)	<0.0005	0.046
Chile versus Spain	-1.35	(-1.56, -1.14)	<0.0005	0.072
Chile versus USA	-1.09	(-1.26, -0.92)	<0.0005	0.058
Chile versus Canada	-2.06	(-2.21, -1.92)	<0.0005	0.049
Mexico versus Spain	-0.52	(-0.69, -0.35)	<0.0005	0.057
Mexico versus USA	-0.26	(-0.37, -0.15)	<0.0005	0.037
Mexico versus Canada	-1.23	(-1.34, -1.12)	<0.0005	0.037
Spain versus USA	0.26	(0.10, 0.42)	<0.0005	0.054
Spain versus Canada	-0.71	(-0.86, -0.56)	<0.0005	0.052
USA versus Canada	-0.97	(-1.08, -0.87)	<0.0005	0.035
Figure Weights				
Colombia versus Chile	0.00	(0.00, 0.00)	--	0.000
Colombia versus Mexico	-0.84	(-0.96, -0.72)	<0.0005	0.041
Colombia versus Spain	-1.54	(-1.70, -1.39)	<0.0005	0.054
Colombia versus USA	-0.89	(-1.03, -0.74)	<0.0005	0.049
Colombia versus Canada	-1.41	(-1.55, -1.28)	<0.0005	0.045
Chile versus Mexico	-0.84	(-0.96, -0.72)	<0.0005	0.041
Chile versus Spain	-1.54	(-1.70, -1.39)	<0.0005	0.054
Chile versus USA	-0.89	(-1.03, -0.74)	<0.0005	0.049
Chile versus Canada	-1.41	(-1.55, -1.28)	<0.0005	0.045
Mexico versus Spain	-0.70	(-0.85, -0.55)	<0.0005	0.052
Mexico versus USA	-0.04	(-0.19, 0.10)	1.0000	0.049
Mexico versus Canada	-0.57	(-0.74, -0.40)	<0.0005	0.058
Spain versus USA	0.66	(0.55, 0.77)	<0.0005	0.036
Spain versus Canada	0.13	(0.00, 0.26)	0.039	0.043
USA versus Canada	-0.53	(-0.61, -0.44)	<0.0005	0.029
Picture Completion				
Colombia versus Chile	0.00	(0.00, 0.00)	--	0.000
Colombia versus Mexico	-0.62	(-0.77, -0.47)	<0.0005	0.051
Colombia versus Spain	-1.26	(-1.37, -1.15)	<0.0005	0.037
Colombia versus USA	-1.44	(-1.55, -1.32)	<0.0005	0.040
Colombia versus Canada	-1.59	(-1.70, -1.48)	<0.0005	0.038
Chile versus Mexico	-0.62	(-0.77, -0.47)	<0.0005	0.051
Chile versus Spain	-1.26	(-1.37, -1.15)	<0.0005	0.037
Chile versus USA	-1.44	(-1.55, -1.32)	<0.0005	0.040
Chile versus Canada	-1.59	(-1.70, -1.48)	<0.0005	0.038
Mexico versus Spain	-0.64	(-0.80, -0.48)	<0.0005	0.055
Mexico versus USA	-0.82	(-0.97, -0.66)	<0.0005	0.052
Mexico versus Canada	-0.97	(-1.13, -0.82)	<0.0005	0.053
Spain versus USA	-0.18	(-0.29, -0.07)	<0.0005	0.037
Spain versus Canada	-0.33	(-0.44, -0.23)	<0.0005	0.036
USA versus Canada	-0.16	(-0.25, -0.06)	<0.0005	0.033
Digit Span				
Colombia versus Chile	0.00	(0.00, 0.00)	--	0.000
Colombia versus Mexico	-0.80	(-0.90, -0.70)	<0.0005	0.035
Colombia versus Spain	-1.66	(-1.78, -1.53)	<0.0005	0.044

	Mean Difference	95% Confidence Interval for Difference	Significance	Standard Error
Colombia versus USA	-2.49	(-2.62, -2.35)	<0.0005	0.045
Colombia versus Canada	-3.36	(-3.47, -3.24)	<0.0005	0.040
Chile versus Mexico	-0.80	(-0.90, -0.70)	<0.0005	0.035
Chile versus Spain	-1.66	(-1.78, -1.53)	<0.0005	0.044
Chile versus USA	-2.49	(-2.62, -2.35)	<0.0005	0.045
Chile versus Canada	-3.36	(-2.47, -3.24)	<0.0005	0.040
Mexico versus Spain	-0.86	(-0.95, -0.75)	<0.0005	0.031
Mexico versus USA	-1.69	(-1.78, -1.59)	<0.0005	0.032
Mexico versus Canada	-2.56	(-2.65, -2.46)	<0.0005	0.032
Spain versus USA	-0.83	(-0.93, -0.73)	<0.0005	0.034
Spain versus Canada	-1.70	(-1.79, -1.61)	<0.0005	0.031
USA versus Canada	-0.87	(-0.96, -0.78)	<0.0005	0.030
Arithmetic				
Colombia versus Chile	0.00	(0.00, 0.00)	--	0.000
Colombia versus Mexico	-0.96	(-1.03, -0.88)	<0.0005	0.025
Colombia versus Spain	-1.23	(-1.37, -1.10)	<0.0005	0.046
Colombia versus USA	-1.65	(-1.77, -1.53)	<0.0005	0.040
Colombia versus Canada	-2.47	(-2.58, -2.35)	<0.0005	0.039
Chile versus Mexico	-0.96	(-1.03, -0.88)	<0.0005	0.025
Chile versus Spain	-1.23	(-1.37, -1.10)	<0.0005	0.046
Chile versus USA	-1.65	(-1.77, -1.53)	<0.0005	0.040
Chile versus Canada	-2.47	(-2.58, -2.35)	<0.0005	0.039
Mexico versus Spain	-0.28	(-0.40, -0.15)	<0.0005	0.044
Mexico versus USA	-0.70	(-0.81, -0.58)	<0.0005	0.040
Mexico versus Canada	-1.51	(-1.62, -1.40)	<0.0005	0.037
Spain versus USA	-0.42	(-0.54, -0.30)	<0.0005	0.041
Spain versus Canada	-1.23	(-1.35, -1.12)	<0.0005	0.038
USA versus Canada	-0.81	(-0.88, -0.74)	<0.0005	0.023
Letter-Number Sequencing				
Colombia versus Chile	0.00	(0.00, 0.00)	--	0.000
Colombia versus Mexico	-0.75	(-0.89, -0.61)	<0.0005	0.047
Colombia versus Spain	-1.66	(-1.84, -1.48)	<0.0005	0.060
Colombia versus USA	-2.01	(-2.23, -1.78)	<0.0005	0.077
Colombia versus Canada	-2.53	(-2.72, -2.33)	<0.0005	0.066
Chile versus Mexico	-0.75	(-0.89, -0.61)	<0.0005	0.047
Chile versus Spain	-1.66	(-1.84, -1.48)	<0.0005	0.060
Chile versus USA	-2.01	(-2.23, -1.78)	<0.0005	0.077
Chile versus Canada	-2.53	(-2.72, -2.33)	<0.0005	0.066
Mexico versus Spain	-0.91	(-1.08, -0.75)	<0.0005	0.056
Mexico versus USA	-1.26	(-1.43, -1.09)	<0.0005	0.059
Mexico versus Canada	-1.78	(-1.92, -1.64)	<0.0005	0.048
Spain versus USA	-0.35	(-0.55, -0.15)	<0.0005	0.067
Spain versus Canada	-0.87	(-1.03, -0.70)	<0.0005	0.056
USA versus Canada	-0.52	(-0.63, -0.41)	<0.0005	0.037
Symbol Search				
Colombia versus Chile	0.00	(0.00, 0.00)	--	0.000

	Mean Difference	95% Confidence Interval for Difference	Significance	Standard Error
Colombia versus Mexico	-0.90	(-1.05, -0.75)	<0.0005	0.050
Colombia versus Spain	-1.44	(-1.55, -1.33)	<0.0005	0.037
Colombia versus USA	-1.21	(-1.33, -1.09)	<0.0005	0.041
Colombia versus Canada	-1.70	(-1.81, -1.58)	<0.0005	0.039
Chile versus Mexico	-0.90	(-1.05, -0.75)	<0.0005	0.050
Chile versus Spain	-1.44	(-1.55, -1.33)	<0.0005	0.037
Chile versus USA	-1.21	(-1.33, -1.09)	<0.0005	0.041
Chile versus Canada	-1.70	(-1.81, -1.58)	<0.0005	0.039
Mexico versus Spain	-0.54	(-0.66, -0.43)	<0.0005	0.040
Mexico versus USA	-0.31	(-0.48, -0.13)	<0.0005	0.060
Mexico versus Canada	-0.80	(-0.99, -0.61)	<0.0005	0.065
Spain versus USA	0.24	(0.10, 0.37)	<0.0005	0.045
Spain versus Canada	-0.26	(-0.39, -0.12)	<0.0005	0.045
USA versus Canada	-0.49	(-0.59, -0.40)	<0.0005	0.033
Coding				
Colombia versus Chile	0.00	(0.00, 0.00)	--	0.000
Colombia versus Mexico	-1.18	(-1.33, -1.03)	<0.0005	0.050
Colombia versus Spain	-1.67	(-1.77, -1.56)	<0.0005	0.035
Colombia versus USA	-1.58	(-1.72, -1.44)	<0.0005	0.047
Colombia versus Canada	-2.12	(-2.24, -1.99)	<0.0005	0.043
Chile versus Mexico	-1.18	(-1.33, -1.03)	<0.0005	0.050
Chile versus Spain	-1.67	(-1.77, -1.56)	<0.0005	0.035
Chile versus USA	-1.58	(-1.72, -1.44)	<0.0005	0.047
Chile versus Canada	-2.12	(-2.24, -1.99)	<0.0005	0.043
Mexico versus Spain	-0.49	(-0.65, -0.32)	<0.0005	0.057
Mexico versus USA	-0.40	(-0.55, -0.25)	<0.0005	0.051
Mexico versus Canada	-0.94	(-1.09, -0.79)	<0.0005	0.050
Spain versus USA	0.08	(-0.04, 0.20)	<0.0005	0.040
Spain versus Canada	-0.45	(-0.56, -0.34)	<0.0005	0.037
USA versus Canada	-0.53	(-0.52, -0.45)	<0.0005	0.029
Cancellation				
Colombia versus Chile	0.00	(0.00, 0.00)	--	0.000
Colombia versus Mexico	-0.75	(-0.94, -0.56)	<0.0005	0.064
Colombia versus Spain	-0.64	(-0.76, -0.53)	<0.0005	0.038
Colombia versus USA	0.02	(-0.07, 0.10)	1.0000	0.030
Colombia versus Canada	-0.02	(-0.14, 0.11)	1.0000	0.041
Chile versus Mexico	-0.75	(-0.94, -0.56)	<0.0005	0.064
Chile versus Spain	-0.64	(-0.76, -0.53)	<0.0005	0.038
Chile versus USA	0.02	(-0.07, 0.10)	1.0000	0.030
Chile versus Canada	-0.02	(-0.14, 0.11)	1.0000	0.041
Mexico versus Spain	0.11	(-0.12, 0.34)	1.0000	0.078
Mexico versus USA	0.77	(0.57, 0.97)	<0.0005	0.068
Mexico versus Canada	0.73	(0.51, 0.96)	<0.0005	0.076
Spain versus USA	0.66	(0.54, 0.78)	<0.0005	0.040
Spain versus Canada	0.63	(0.51, 0.74)	<0.0005	0.038
USA versus Canada	-0.03	(-0.12, 0.05)	1.0000	0.029

Supplemental Table 2.1. Demographic Statistics for the Chilean WAIS-IV Ages 16-69 (N=672)

	M	*SD*
Age	36.93	17.12
Age Band	*N*	%
16-17	76	11.3
18-19	75	11.2
20-24	78	11.6
25-29	71	10.6
30-34	78	11.6
35-44	74	11.0
45-54	73	10.9
55-64	81	12.1
65-69	66	9.8
Sex		
Men	333	49.6
Women	339	50.4
Education Level		
Level 1	215	32.0
Level 2	239	35.6
Level 3	218	32.4
Region		
Santiago	301	44.8
Arica	56	8.3
Iquique	52	7.7
Antofagasta	51	7.6
Concepción	103	15.3
Temuco	52	7.7
Punta Arenas	57	7.8

Supplemental Table 2.2. Subtest and Index Descriptive Statistics for the Chilean WAIS-IV Ages 16-69 (N=672)

	M	*SD*	Skewness	Kurtosis
SI	10.02	3.06	-0.07	-0.21
VC	9.94	3.12	-0.11	-0.56
IN	10.02	3.13	0.03	-1.08
CO	10.06	3.01	-0.16	-0.54
BD	9.98	3.02	0.02	-0.39
MR	10.18	3.39	0.05	-1.03
VP	10.04	2.99	0.29	-0.63
FW	9.99	3.08	0.19	-0.20
PC	9.99	3.10	-0.09	-0.41
DS	10.11	3.04	0.06	0.07
AR	10.06	2.92	0.36	-0.15
LN	9.90	3.06	0.36	1.26
SS	9.97	3.04	0.07	0.02
CD	10.01	3.01	0.05	-0.15
CA	10.00	2.96	0.11	0.28
VCI	101.10	15.17	-0.17	-0.66
PRI	100.75	15.58	0.18	-0.49
WMI	101.50	15.38	0.19	-0.03
PSI	101.66	15.24	0.01	0.06
FSIQ	100.38	15.37	-0.13	-0.39

Note. SI = Similarities, VC = Vocabulary, IN = Information, CO = Comprehension, BD = Block Design, MR = Matrix Reasoning, VP = Visual Puzzles, FW = Figure Weights, PC = Picture Completion, DS = Digit Span, AR = Arithmetic, LN = Letter-Number Sequencing, SS = Symbol Search, CD = Coding, CA = Cancellation

Supplemental Table 2.3. Correlation Matrix for the Chilean WAIS-IV Ages 16-69 (N=672)

	SI	VC	IN	CO	BD	MR	VP	FW	PC	DS	AR	LN	SS	CD	CA	VCI	PRI	WMI	PSI	FSIQ
SI	1																			
VC	0.70	1																		
IN	0.65	0.72	1																	
CO	0.66	0.73	0.65	1																
BD	0.46	0.50	0.54	0.46	1															
MR	0.53	0.56	0.62	0.54	0.56	1														
VP	0.41	0.48	0.51	0.42	0.63	0.55	1													
FW	0.53	0.56	0.59	0.53	0.57	0.58	0.56	1												
PC	0.47	0.50	0.51	0.45	0.53	0.47	0.50	0.48	1											
DS	0.50	0.56	0.55	0.47	0.47	0.54	0.46	0.55	0.42	1										
AR	0.52	0.54	0.55	0.47	0.54	0.58	0.54	0.63	0.43	0.63	1									
LN	0.52	0.53	0.56	0.49	0.46	0.55	0.44	0.56	0.43	0.74	0.57	1								
SS	0.39	0.43	0.40	0.41	0.43	0.41	0.39	0.43	0.40	0.42	0.42	0.44	1							
CD	0.46	0.50	0.48	0.49	0.48	0.47	0.39	0.48	0.43	0.49	0.44	0.47	0.66	1						
CA	0.34	0.30	0.32	0.28	0.31	0.30	0.33	0.34	0.35	0.35	0.36	0.36	0.49	0.43	1					
VCI	0.88	0.91	0.89	0.76	0.56	0.64	0.52	0.63	0.56	0.60	0.60	0.60	0.46	0.54	0.36	1				
PRI	0.55	0.61	0.66	0.56	0.85	0.84	0.85	0.67	0.59	0.58	0.65	0.57	0.49	0.53	0.37	0.68	1			
WMI	0.57	0.61	0.61	0.52	0.56	0.62	0.56	0.65	0.47	0.91	0.90	0.73	0.46	0.52	0.40	0.67	0.69	1		
PSI	0.46	0.51	0.48	0.49	0.50	0.48	0.43	0.50	0.46	0.50	0.47	0.50	0.91	0.91	0.51	0.55	0.55	0.54	1	
FSIQ	0.75	0.80	0.81	0.71	0.75	0.78	0.71	0.73	0.62	0.75	0.77	0.71	0.66	0.72	0.47	0.88	0.88	0.84	0.75	1

Note. SI = Similarities, VC = Vocabulary, IN = Information, CO = Comprehension, BD = Block Design, MR = Matrix Reasoning, VP = Visual Puzzles, FW = Figure Weights, PC = Picture Completion, DS = Digit Span, AR = Arithmetic, LN = Letter-Number Sequencing, SS = Symbol Search, CD = Coding, CA = Cancellation, VCI = Verbal Comprehension Index, PRI = Performance Reasoning Index, WMI = Working Memory Index, PSI = Processing Speed Index.

Supplemental Table 2.4. Factor loadings for indicators of FSIQ/*g* across all best Wechsler and CHC factor models

	4-Factor Higher-Order	4-Factor Higher-Order (SL Trans.)	4-Factor Bifactor	Benson 5-Factor Higher-Order	Benson 5-Factor Higher-Order (SL Trans.)	Benson 5-Factor Bifactor	Weiss 5-Factor Higher-Order	Weiss 5-Factor Higher-Order (SL Trans.)	Weiss 5-Factor Bifactor	Mean (4 & 5-Factor Models)	Mean (5-Factor Models Only)	First Order/ Index Level Factor	
SI	0.802	0.701	~~0.725~~	0.802	0.695	0.795	0.802	0.702	0.801	0.762	0.766	**VCI**	**Gc**
VC	0.872	0.762	~~0.767~~	0.871	0.754	0.862	0.871	0.762	0.868	0.828	0.831	**VCI**	**Gc**
IN	0.831	0.726	~~0.797~~	0.832	0.721	0.853	0.832	0.728	0.840	0.795	0.801	**VCI**	**Gc**
CO	0.808	0.706	~~0.710~~	0.808	0.700	0.807	0.808	0.707	0.820	0.770	0.775	**VCI**	**GC**
BD	0.769	0.720	~~0.659~~	0.802	0.716	0.604	0.802	0.702	**0.593**	0.713	0.703	**PRI**	**Gv**
MR	0.766	0.717	~~0.750~~	0.768	0.764	0.689	**0.586**	**0.586**	0.681	0.695	0.679	**PRI**	**Gf**
VP	0.739	0.692	~~0.617~~	0.766	0.684	**0.567**	0.767	0.671	**0.555**	0.680	0.668	**PRI**	**Gv**
FW	**0.403**	**0.377**	~~0.741~~	0.786	0.782	0.678	**0.144**	**0.126**	0.671	**0.496**	**0.531**	**PRI/WMI**	**Gf**
PC	0.665	0.622	~~0.620~~	0.677	0.665	0.588	0.676	**0.592**	**0.582**	0.633	0.630	**PRI**	**Gv**
DS	0.761	0.712	~~0.706~~	0.874	0.719	0.636	0.874	0.725	0.629	0.741	0.743	**WMI**	**Gsm**
AR	0.800	0.749	~~0.699~~	**0.400**	**0.363**	0.636	**0.261**	**0.217**	0.628	**0.507**	**0.417**	**WMI**	**Gf/Gsm**
LN	0.739	0.692	~~0.714~~	0.849	0.699	0.640	**0.484**	**0.402**	0.633	0.642	0.618	**WMI**	**Gsm**
SS	0.797	0.608	~~0.552~~	0.798	0.599	**0.487**	0.874	0.662	**0.490**	0.664	0.652	**PSI**	**Gs**
CD	0.823	0.628	~~0.636~~	0.823	0.618	**0.582**	**0.261**	**0.198**	**0.584**	**0.565**	**0.511**	**PSI**	**Gs**
CA	**0.576**	**0.439**	~~0.440~~	**0.575**	**0.432**	**0.380**	**0.484**	**0.366**	**0.379**	**0.454**	**0.436**	**PSI**	**Gs**

Note. SL Trans. = Schmid-Leiman transformation (Schmid-Leiman, 1957; Brown, 2015). SI = Similarities, VC = Vocabulary, IN = Information, CO = Comprehension, BD = Block Design, MR = Matrix Reasoning, VP = Visual Puzzles, FW = Figure Weights, PC = Picture Completion, DS = Digit Span, AR = Arithmetic, LN = Letter-Number Sequencing, SS = Symbol Search, CD = Coding, CA = Cancellation, VCI = Verbal Comprehension Index, PRI = Performance Reasoning Index, WMI = Working Memory Index, PSI = Processing Speed Index, Gc = crystalized intelligence, Gf = fluid intelligence, Gv = visual processing, Gsm = short-term memory, Gs = processing speed. Benson = Benson et al., 2010; Weiss = Weiss et al., 2013. Factor loadings below 0.600. are bolded in red. Factor loading calculations from Duggan (Dissertation Paper 2).

Supplemental Table 3.1. Mean factor loadings for indicators of FSIQ/g across best Wechsler and CHC factor models

Subtest	Mean Factor Loading	4-Factor Index
VC*	0.828	VCI
IN*	0.795	VCI
CO	0.770	VCI
SI	0.762	VCI
BD*	0.713	PRI
MR*	0.695	PRI
VP*	0.680	PRI
PC	0.633	PRI
FW	**0.496**	PRI/WMI
DS*	0.741	WMI
LN*	0.642	WMI
AR	**0.507**	WMI
SS*	0.664	PSI
CD^	**0.565**	PSI
CA	**0.454**	PSI

Subtest	Mean Factor Loading	5-Factor Index
VC*	0.828	Gc
IN*	0.795	Gc
CO	0.770	Gc
SI	0.762	Gc
BD*	0.713	Gv
VP*	0.680	Gv
PC	0.633	Gv
MR*	0.695	Gf
AR^	**0.507**	Gf/Gsm
FW	**0.496**	Gf
DS*	0.741	Gsm
LN*	0.642	Gsm
SS*	0.664	Gs
CD^	**0.565**	Gs
CA	**0.454**	Gs

Note. FSIQ = Full-scale Intelligence Quotient. SI = Similarities, VC = Vocabulary, IN = Information, CO = Comprehension, BD = Block Design, MR = Matrix Reasoning, VP = Visual Puzzles, FW = Figure Weights, PC = Picture Completion, DS = Digit Span, AR = Arithmetic, LN = Letter-Number Sequencing, SS = Symbol Search, CD = Coding, CA = Cancellation, VCI = Verbal Comprehension Index, PRI = Performance Reasoning Index, WMI = Working Memory Index, PSI = Processing Speed Index, Gc = crystalized intelligence, Gf = fluid intelligence, Gv = visual processing, Gsm = short-term memory, Gs = processing speed. Factor loadings below 0.600. are bolded in red. Mean factor loading calculations from Duggan & Garcia-Barrera, 2019) and Supplemental Table 1.

Supplemental Table 3.2. Two-, three-, four-, and five-subtest Chilean WAIS-IV short forms with the highest mean reliability and validity coefficients

	Two subtests				Three subtests					Four subtests						Five subtests							
Comb.	***Short form***		r_{ss}	r	***Short form***			r_{ss}	r	***Short form***				r_{ss}	r	***Short form***					r_{ss}	r	**Comb.**
C1	IN	MR	0.941	0.857	VC	MR	DS	0.948	0.898	VC	IN	MR	DS	0.964	0.918	VC	IN	MR	DS	LN	0.949	0.924	C1
C2	IN	DS	0.938	0.864	IN	MR	DS	0.952	0.893	SI	IN	MR	DS	0.963	0.918	VC	IN	MR	VP	DS	0.947	0.936	C2
C3	VC	MR	0.934	0.860	VC	MR	LN	0.941	0.903	VC	IN	MR	LN	0.960	0.917	VC	IN	MR	VP	LN	0.944	0.934	C3
C4	VC	DS	0.932	0.859	VC	MR	VP	0.940	0.902	VC	IN	MR	VP	0.960	0.913	VC	IN	MR	PC	DS	0.944	0.933	C4
C5	IN	VP	0.925	0.849	IN	MR	LN	0.946	0.894	SI	IN	MR	LN	0.960	0.915	VC	IN	VP	DS	LN	0.943	0.930	C5
C6	IN	LN	0.925	0.865	IN	MR	VP	0.945	0.892	SI	IN	MR	VP	0.959	0.913	IN	CO	MR	VP	DS	0.941	0.934	C6
C7	MR	DS	0.923	0.848	CO	MR	DS	0.930	0.900	VC	IN	VP	DS	0.958	0.924	VC	IN	BD	MR	DS	0.941	0.935	C7
C8	VC	LN	0.918	0.863	SI	MR	DS	0.930	0.896	IN	CO	MR	DS	0.957	0.916	VC	IN	MR	PC	LN	0.940	0.931	C8
C9	VC	VP	0.918	0.848	IN	VP	DS	0.945	0.880	SI	IN	VP	DS	0.957	0.927	VC	CO	MR	VP	DS	0.939	0.932	C9
C10	CO	MR	0.915	0.836	VC	VP	DS	0.941	0.883	IN	MR	VP	DS	0.956	0.918	VC	IN	VP	PC	DS	0.939	0.933	C10
C11	IN	PC	0.914	0.832	VC	BD	MR	0.930	0.893	VC	IN	PC	DS	0.955	0.914	IN	CO	MR	VP	LN	0.937	0.931	C11
C12	MR	LN	0.912	0.838	CO	MR	LN	0.925	0.896	VC	IN	VP	LN	0.954	0.924	VC	IN	MR	DS	SS	0.937	0.939	C12
C13	VP	DS	0.907	0.829	VC	MR	PC	0.935	0.887	SI	IN	PC	DS	0.954	0.915	IN	CO	MR	PC	DS	0.937	0.932	C13
C14	VC	PC	0.906	0.830	VC	VP	LN	0.934	0.888	SI	IN	VP	LN	0.953	0.924	VC	IN	BD	MR	LN	0.937	0.935	C14
C15	SI	MR	0.901	0.842	VC	BD	DS	0.929	0.892	VC	MR	VP	DS	0.953	0.922	SI	IN	MR	VP	DS	0.937	0.935	C15
C16					IN	BD	DS	0.933	0.887	SI	MR	VP	DS	0.952	0.921	VC	IN	BD	VP	DS	0.936	0.933	C16
C17					IN	DS	SS	0.925	0.895	VC	IN	BD	DS	0.952	0.922	SI	VC	MR	VP	DS	0.935	0.934	C17
C18					IN	VP	LN	0.938	0.881	IN	CO	VP	DS	0.951	0.924	IN	CO	BD	MR	DS	0.934	0.933	C18
C19					SI	MR	VP	0.920	0.899	SI	IN	BD	DS	0.951	0.924	VC	IN	MR	LN	SS	0.933	0.936	C19
C20					IN	MR	SS	0.927	0.891	VC	MR	PC	DS	0.949	0.921	VC	IN	MR	VP	SS	0.933	0.935	C20
C21					VC	BD	LN	0.921	0.896	IN	CO	VP	LN	0.947	0.921	VC	IN	VP	DS	SS	0.931	0.942	C21
C22					IN	MR	PC	0.940	0.877	SI	IN	DS	SS	0.947	0.922	IN	CO	MR	DS	SS	0.930	0.937	C22
C23					IN	BD	MR	0.936	0.880	VC	BD	MR	DS	0.946	0.923	SI	VC	MR	PC	DS	0.930	0.939	C23
C24					SI	MR	LN	0.925	0.890	IN	MR	DS	SS	0.944	0.924	IN	MR	VP	DS	SS	0.929	0.938	C24
C25					IN	BD	LN	0.927	0.888	CO	MR	PC	DS	0.940	0.930	VC	IN	VP	LN	SS	0.927	0.940	C25

Note. SI = Similarities, VC = Vocabulary, IN = Information, CO = Comprehension, BD = Block Design, MR = Matrix Reasoning, VP = Visual Puzzles, FW = Figure Weights, PC = Picture Completion, DS = Digit Span, AR = Arithmetic, LN = Letter-Number Sequencing, SS = Symbol Search, CD = Coding, CA = Cancellation. Comb. = combination number.

Supplemental Table 3.3. Model Fit and Factor Loadings of Select Two-, Three-, Four-, and Five-Subtest Short Forms

Comb.	T1	T2	T3	T4	T5	c^2	*df*	CFI	TLI	RMSEA	lT1	lT2	lT3	lT4	lT5	mean l	exclude?
Two-subtests																	
C1	IN	MR	-	-	-	-	*	-	-	-	-	-	-	-	-	-	-
C2	IN	DS	-	-	-	-	*	-	-	-	-	-	-	-	-	-	-
C3	VC	MR	-	-	-	-	*	-	-	-	-	-	-	-	-	-	-
C4	VC	DS	-	-	-	-	*	-	-	-	-	-	-	-	-	-	-
C5	IN	VP	-	-	-	-	*	-	-	-	-	-	-	-	-	-	-
C6	IN	LN	-	-	-	-	*	-	-	-	-	-	-	-	-	-	-
C7	MR	DS	-	-	-	-	*	-	-	-	-	-	-	-	-	-	-
C8	VC	LN	-	-	-	-	*	-	-	-	-	-	-	-	-	-	-
C9	VC	VP	-	-	-	-	*	-	-	-	-	-	-	-	-	-	-
C10	CO	MR	-	-	-	-	*	-	-	-	-	-	-	-	-	-	-
C11	IN	PC	-	-	-	-	*	-	-	-	-	-	-	-	-	-	-
C12	MR	LN	-	-	-	-	*	-	-	-	-	-	-	-	-	-	-
C13	VP	DS	-	-	-	-	*	-	-	-	-	-	-	-	-	-	-
C14	VC	PC	-	-	-	-	*	-	-	-	-	-	-	-	-	-	-
C15	SI	MR	-	-	-	-	*	-	-	-	-	-	-	-	-	-	-
Three-subtests																	
C1	VC	MR	DS	-	-	-	*	-	-	-	0.761	0.741	0.732	-	-	0.745	
C2	IN	MR	DS	-	-	-	*	-	-	-	0.789	0.782	0.693	-	-	0.755	
C3	VC	MR	LN	-	-	-	*	-	-	-	0.736	0.766	0.718	-	-	0.740	
C4	VC	MR	VP	-	-	-	*	-	-	-	0.705	0.800	0.685	-	-	0.730	
C5	IN	MR	LN	-	-	-	*	-	-	-	0.792	0.780	0.706	-	-	0.759	
C6	IN	MR	VP	-	-	-	*	-	-	-	0.759	0.813	0.673	-	-	0.748	
C7	CO	MR	DS	-	-	-	*	-	-	-	0.789	0.782	0.693	-	-	0.755	
C8	SI	MR	DS	-	-	-	*	-	-	-	0.704	0.758	0.715	-	-	0.726	
C9	IN	VP	DS	-	-	-	*	-	-	-	0.779	0.656	0.701	-	-	0.712	
C10	VC	VP	DS	-	-	-	*	-	-	-	0.765	0.631	0.729	-	-	0.708	
C11	VC	BD	MR	-	-	-	*	-	-	-	0.709	0.700	0.796	-	-	0.735	
C12	CO	MR	LN	-	-	-	*	-	-	-	0.792	0.780	0.706	-	-	0.759	
C13	VC	MR	PC	-	-	-	*	-	-	-	0.772	0.730	0.644	-	-	0.715	
C14	VC	VP	LN	-	-	-	*	-	-	-	0.765	0.631	0.729	-	-	0.708	
C15	VC	BD	DS	-	-	-	*	-	-	-	0.763	0.650	0.730	-	-	0.714	
C16	IN	BD	DS	-	-	-	*	-	-	-	0.791	0.687	0.691	-	-	0.723	
C17	IN	DS	SS	-	-	-	*	-	-	-	0.722	0.757	0.557	-	-	0.679	
C18	IN	VP	LN	-	-	-	*	-	-	-	0.805	0.635	0.695	-	-	0.712	
C19	SI	MR	VP	-	-	-	*	-	-	-	0.629	0.848	0.645	-	-	0.707	
C20	IN	MR	SS	-	-	-	*	-	-	-	0.777	0.794	0.517	-	-	0.696	Y
C21	VC	BD	LN	-	-	-	*	-	-	-	0.759	0.653	0.696	-	-	0.703	
C22	IN	MR	PC	-	-	-	*	-	-	-	0.818	0.754	0.623	-	-	0.732	
C23	IN	BD	MR	-	-	-	*	-	-	-	0.776	0.700	0.795	-	-	0.757	
C24	SI	MR	LN	-	-	-	*	-	-	-	0.713	0.749	0.735	-	-	0.732	
C25	IN	BD	LN	-	-	-	*	-	-	-	0.817	0.665	0.684	-	-	0.722	
Four-subtests																	
C1	VC	IN	MR	DS	-	17.8	2	0.987	0.960	0.108	0.824	0.855	0.720	0.673	-	0.768	Y
C2	SI	IN	MR	DS	-	10.9	2	0.992	0.975	0.081	0.757	0.840	0.738	0.675	-	0.753	Y
C3	VC	IN	MR	LN	-	17.9	2	0.986	0.959	0.109	0.812	0.865	0.722	0.669	-	0.767	Y
C4	VC	IN	MR	VP	-	30.2	2	0.975	0.925	0.145	0.810	0.963	0.728	0.624	-	0.781	Y
C5	SI	IN	MR	LN	-	10.5	2	0.992	0.976	0.079	0.760	0.838	0.738	0.693	-	0.757	
C6	SI	IN	MR	VP	-	30.2	2	0.972	0.917	0.145	0.738	0.847	0.749	0.623	-	0.739	Y
C7	VC	IN	VP	DS	-	10.1	2	0.992	0.976	0.078	0.838	0.847	0.604	0.666	-	0.739	
C8	IN	CO	MR	DS	-	11.3	2	0.991	0.973	0.083	0.842	0.750	0.746	0.664	-	0.751	Y
C9	SI	IN	VP	DS	-	14.9	2	0.986	0.957	0.098	0.753	0.851	0.599	0.666	-	0.717	
C10	IN	MR	VP	DS	-	1.4	2	1.000	1.002	0.000	0.775	0.798	0.672	0.690	-	0.734	

C11	VC	IN	PC	DS	-	1.7	2	1.000	1.001	0.000	0.846	0.845	0.601	0.657	-	0.737	
C12	VC	IN	VP	LN	-	5.7	2	0.996	0.989	0.053	0.822	0.865	0.600	0.654	-	0.735	
C13	SI	IN	PC	DS	-	1.7	2	1.000	1.001	0.000	0.846	0.845	0.601	0.657	-	0.737	
C14	SI	IN	VP	LN	-	0.6	2	1.000	1.005	0.000	0.777	0.837	0.614	0.655	-	0.721	
C15	VC	MR	VP	DS	-	6.8	2	0.995	0.984	0.060	0.742	0.775	0.671	0.714	-	0.726	
C16	SI	MR	VP	DS	-	8.1	2	0.992	0.977	0.067	0.671	0.798	0.659	0.702	-	0.708	
C17	VC	IN	BD	DS	-	12.0	2	0.991	0.972	0.086	0.831	0.854	0.631	0.666	-	0.746	Y
C18	IN	CO	VP	DS	-	11.7	2	0.989	0.967	0.085	0.857	0.744	0.606	0.653	-	0.715	Y
C19	SI	IN	BD	DS	-	9.1	2	0.992	0.977	0.073	0.758	0.847	0.642	0.665	-	0.728	
C20	VC	MR	PC	DS	-	3.6	2	0.998	0.994	0.035	0.775	0.744	0.623	0.713	-	0.714	
C21	IN	CO	VP	LN	-	6.3	2	0.995	0.986	0.056	0.861	0.745	0.599	0.660	-	0.716	
C22	SI	IN	DS	SS	-	13.3	2	0.986	0.959	0.092	0.777	0.825	0.671	0.516	-	0.697	Y
C23	VC	BD	MR	DS	-	6.1	2	0.995	0.986	0.055	0.742	0.687	0.773	0.715	-	0.729	Y
C24	IN	MR	DS	SS	-	4.7	2	0.997	0.990	0.045	0.778	0.779	0.709	0.540	-	0.702	Y
C25	CO	MR	PC	DS	-	1.4	2	1.000	1.002	0.000	0.704	0.778	0.616	0.685	-	0.696	Y
Five-subtests																	
C1	VC	IN	MR	DS	LN	188.6	5	0.897	0.794	0.234	0.775	0.798	0.731	0.774	0.772	0.770	Y
C2	VC	IN	MR	VP	DS	41.0	5	0.976	0.952	0.104	0.811	0.842	0.744	0.637	0.684	0.744	Y
C3	VC	IN	MR	VP	LN	39.6	5	0.977	0.953	0.101	0.803	0.850	0.747	0.633	0.678	0.742	Y
C4	VC	IN	MR	PC	DS	20.1	5	0.990	0.979	0.067	0.822	0.850	0.727	0.611	0.676	0.737	
C5	VC	IN	VP	DS	LN	28.2	5	0.981	0.962	0.083	0.837	0.833	0.616	0.680	0.530	0.699	Y
C6	IN	CO	MR	VP	DS	11.9	5	0.995	0.989	0.045	0.839	0.748	0.750	0.613	0.667	0.723	
C7	VC	IN	BD	MR	DS	38.6	5	0.978	0.956	0.100	0.808	0.846	0.661	0.743	0.684	0.748	Y
C8	VC	IN	MR	PC	LN	21.2	5	0.989	0.978	0.069	0.812	0.857	0.730	0.615	0.675	0.738	
C9	VC	CO	MR	VP	DS	89.0	5	0.941	0.882	0.158	0.850	0.793	0.716	0.608	0.667	0.727	Y
C10	VC	IN	VP	PC	DS	34.6	5	0.978	0.955	0.094	0.829	0.841	0.629	0.626	0.669	0.719	Y
C11	IN	CO	MR	VP	LN	28.3	5	0.983	0.966	0.083	0.828	0.735	0.771	0.637	0.685	0.731	Y
C12	VC	IN	MR	DS	SS	31.7	5	0.981	0.961	0.089	0.825	0.841	0.727	0.686	0.526	0.721	Y
C13	IN	CO	MR	PC	DS	11.9	5	0.995	0.989	0.045	0.839	0.748	0.750	0.613	0.667	0.723	
C14	VC	IN	BD	MR	LN	36.5	5	0.979	0.958	0.097	0.801	0.853	0.657	0.746	0.677	0.747	Y
C15	SI	IN	MR	VP	DS	35.6	5	0.977	0.955	0.095	0.735	0.827	0.765	0.637	0.686	0.730	Y
C16	VC	IN	BD	VP	DS	114.2	5	0.926	0.852	0.180	0.805	0.831	0.690	0.667	0.678	0.734	Y
C17	SI	VC	MR	VP	DS	72.4	5	0.951	0.902	0.142	0.777	0.834	0.723	0.612	0.688	0.727	Y
C18	IN	CO	BD	MR	DS	23.2	5	0.987	0.973	0.074	0.828	0.735	0.674	0.767	0.675	0.736	
C19	VC	IN	MR	LN	SS	38.6	5	0.976	0.951	0.100	0.813	0.848	0.731	0.685	0.529	0.721	Y
C20	VC	IN	MR	VP	SS	43.1	5	0.971	0.942	0.107	0.813	0.847	0.737	0.627	0.522	0.709	Y
C21	VC	IN	VP	DS	SS	31.7	5	0.981	0.961	0.089	0.825	0.841	0.727	0.686	0.526	0.721	Y
C22	IN	CO	MR	DS	SS	24.0	5	0.985	0.969	0.075	0.825	0.752	0.753	0.679	0.534	0.709	Y
C23	SI	VC	MR	PC	DS	31.1	5	0.981	0.961	0.088	0.798	0.844	0.700	0.608	0.673	0.725	Y
C24	IN	MR	VP	DS	SS	7.6	5	0.998	0.995	0.028	0.770	0.790	0.678	0.701	0.546	0.697	Y
C25	VC	IN	VP	LN	SS	33.2	5	0.977	0.954	0.092	0.825	0.845	0.614	0.671	0.533	0.698	Y

Note. Comb. = combination number (as referred to in Table X), T = subtest (T1-T5), c^2 = chi-square test, df = degrees of freedom CFI = comparative fit index, TLI = Tucker-Lewis index, RMSEA= root mean square error of approximation, l = factor loading for subtest (T1-T5). SI = Similarities, VC = Vocabulary, IN = Information, CO = Comprehension, BD = Block Design, MR = Matrix Reasoning, VP = Visual Puzzles, PC = Picture Completion, DS = Digit Span, LN = Letter-Number Sequencing, SS = Symbol Search. Combinations highlighted in blue are most theoretically consistent with the Wechsler (4-factor) model. * two-subtest short form models have negative degrees of freedom and three-subtest short form models have zero degrees of freedom; thus, fit statistics cannot be estimated. Y = one or more model parameters below established cutoffs, indicating "yes", exclude from further consideration.