

Validity evidence for the 4th edition of the Wechsler Intelligence Scale for Children

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Abstract

This study aimed to find validity evidence for the WISC-IV through the relationship with external variables, analyzing possible associations between the factor indexes of the WISC-IV and a Cloze test that assesses reading comprehension. We evaluated 150 children ages 6-14 years, from the 1st to the 9th grade level. The statistical technique of structural equation modeling was applied through the program *Analysis of Moment Structures* (AMOS). According to the results the factor index that best predicts reading comprehension is verbal comprehension, revealing a strong association with crystallized cognitive abilities. The results show validity evidence favorable to the WISC-IV interpretations, helping to bring it closer to more contemporary instruments in the assessment of intelligence as proposed by the CHC model.

Keywords: Intelligence; Cloze test; Psychological assessment.

Evidências de validade para a 4^a edição das Escalas Wechsler de Inteligência para Crianças

Resumo

Este estudo teve como propósito buscar evidências de validade por meio da relação com variáveis externas para o WISC-IV, analisando possíveis associações entre os índices fatoriais do WISC-IV e o Teste de Cloze, que avalia a compreensão de leitura. Foram avaliadas 150 crianças com idades entre 6 a 14 anos, do 1^o ao 9^o ano do ensino fundamental. Recorreu-se à técnica estatística modelagem de equações estruturais, por meio do programa *Analysis of Moment Structures* – AMOS. De acordo com os resultados encontrados o índice fatorial que mais prediz a compreensão de leitura é o de compreensão verbal, revelando forte associação com as habilidades cognitivas cristalizadas. Os resultados revelam evidências de validade favoráveis às interpretações do WISC-IV, contribuindo para aproximá-lo de instrumentos mais contemporâneos na avaliação da inteligência, como propõe o modelo CHC.

Palavras-chave: Inteligência; Teste de Cloze; Avaliação psicológica.

Evidencias de validez para la 4^a edición de la Escala de Inteligencia de Wechsler para Niños

Resumen

El objetivo del estudio fue buscar evidencias de validez para el WISC-IV por medio de la relación con variables externas, analizando las posibles asociaciones entre sus índices factoriales y la Prueba de Cloze, que evalúa la comprensión lectora. Fueron evaluados 150 niños con edades entre 6 y 14 años, del 1^o al 9^o grado de la enseñanza primaria. Fue utilizada la técnica estadística de modelaje de ecuaciones estructurales por medio del programa *Analysis of Moment Structures* – AMOS. Los resultados encontrados mostraron que el índice fatorial que más predice la comprensión lectora es el de la comprensión verbal, revelando una asociación fuerte con las habilidades cognitivas cristalizadas. Los resultados muestran evidencias de validez favorables para las interpretaciones del WISC-IV, contribuyendo para aproximarlo de instrumentos más contemporáneos para la evaluación de la inteligencia, como propone el modelo CHC.

Palabras clave: Inteligencia; Prueba de Cloze; Evaluación psicológica.

Intelligence is one of the most researched constructs in psychological science, and since the late nineteenth century, researchers such as Galton and Wundt have studied this phenomenon in their labs (Cohen, Swerdlik, & Sturman, 2014; Urbina, 2007). Despite many studies, there is no consensus on its definition, but Sternberg (2000) suggests a concept that reconciles different positions. The concept refers to intelligence as the individual's ability to learn through experience and adapt to the environment, using metacognitive processes to make learning and adaptation more successful.

Equally important as this concept is comprehension of how intelligence develops and the identification of which cognitive processes, structures and functions of the brain are linked to this construct. As pointed out by Laros, Valentini, Gomes and Andrade (2014) there are three main aspects to the study of intelligence: evolution (development), experimental (cognitive processes), and differential (composed of multidimensional capacities and abilities). Therefore, any intelligence assessment tool must consider these three aspects, as it is important to clearly define for which population and age a test is intended (evolutionary), and which intelligence capacities will be prioritized in the measurement (differential), so that one may understand which cognitive processes tend to be demanded at the time the subject performs the instrument's tasks (experimental).

Among these three aspects to the study of intelligence, there is no way to define which is the most relevant. However, when constructing an instrument, the first step is to ascertain the construct being evaluated by means of the tool. In the case of intelligence tests, it is necessary to define which skills will be measured, and this point is part of the differential aspect. This aspect is based on the psychometric approach, whose conception of intelligence is sustained in factor analysis, a method that enables identification of subgroups of tasks/items that assess the same cognitive ability. From this perspective, a person who has developed a specific cognitive ability should have high scores on tests composed of tasks/items that assess the same skill (Primi, 2003).

Through the years, various psychometric approach models have been proposed to explain the structure of intelligence and the latest model is called the Cattell-Horn-Carroll Cognitive Skills Model, better known as CHC. This model was proposed by McGrew and Flanagan (1998) and is a synthesis of the concepts of Horn (1985), Cattell (1971), and Carroll (1997), which assume the multidimensional and hierarchical structure of intelligence. Since 1998 the CHC model has undergone revisions, particularly in relation to the

quantity of intelligence capacities: it initially has 10 and, in 2009, researcher McGrew added six.

In the latest model's structure, as suggested by Schneider and McGrew (2012), there were some changes regarding the classifications, definitions and understanding of the groupings among the capacities, though the total remained 16 and they maintained the original idea of a tri-stratum model. The first one is the base, consisting of approximately 80 intelligence capacities, for example, reading and inductive reasoning. The second stratum, which is comprised of capabilities such as fluid intelligence, are broad in their dimensions and are related to the first-stratum skills. Finally, a single dimension called general intelligence represents the third stratum, at the top, which pertains to the other strata. The 16 capacities contained in the second stratum, and were presented in the most recent version of the CHC model are: fluid reasoning (fluid intelligence) (*Gf*), short-term memory (*Gsm*), long-term memory storage and retrieval (*Glr*), processing speed (cognitive speed) (*Gs*), reaction and decision speed (*Gt*), psychomotor speed (*Gps*), comprehension-knowledge (crystallized intelligence) (*Gc*), domain-specific knowledge (*Gkn*), reading and writing (*Grw*), quantitative knowledge (*Gq*), visual processing (*Gv*), auditory processing (*Ga*), olfactory abilities (*Go*), tactile abilities (*Gh*), kinesthetic abilities (*Gk*) and psychomotor abilities (*Gp*).

At the time of their study, Flanagan and McGrew (1998) concluded that no battery of intelligence tests available in the United States included at least two subtests for each of the ten broad skills (currently 16), which is the minimum criterion to serve this model. Thus, several authors have revised their batteries in attempt to meet this criterion, as with the Woodcock-Johnson III (WJ-III), currently considered the most complete intelligence assessment within the CHC model. The factor structure and high correlations between tasks that make up the strata of the CHC model attest to its construct validity. The battery consists of two versions; one evaluates the cognitive abilities and other academic performance (Wechsler & Schelini, 2006).

In the last decade, the CHC theory has been used to gain understanding of the structural of human intelligence and nature of cognitive functions that the various instruments and batteries evaluate (Flanagan & Ortiz, 2001; McGrew, 2009). In Brazil there is need for adaptation or development of a greater number of tools to enable a broader intellectual assessment. Accordingly, it is expected that the propagation of theoretical models such as the CHC will allow intelligence to be understood not as a single, innate and

static capacity, but as comprising multiple capacities, capable of development (Schelini, 2006).

The Wechsler scales are among the main instruments used in Brazil to evaluate intelligence, which seek to assess intelligence in a two-dimensional approach, categorizing IQ scores in verbal and non-verbal or execution. These scales have provided significant advances in understanding the assessment of cognitive abilities (Vanderwood, McGrew, Flanagan, & Keith, 2002). The Wechsler Intelligence Scale for Children (WISC) is now in its 4th edition, published in 2003 in the United States and in 2013 in Brazil. The instrument is constantly modified to adhere to the most contemporary conceptions of intelligence, as well as to update the IQ scores of a population that suffers effects of time (Figueiredo, Vidal, & Nascimento, 2012).

In Brazil, there is a need for research with validated and standardized psychological instruments that meet the minimum criteria of the CHC model. According to Figueiredo, Vidal and Nascimento (2012), the Wechsler Intelligence Scales strongly evaluate three factors the second stratum of the CHC model, namely, crystallized intelligence (*Gc*), through the subtests Information, Similarities, Vocabulary, and Comprehension; visual processing (*Gv*), through the subtests Picture Completion and Block Design; and finally, processing speed (*Gs*), by subtests Symbol Search and Coding. However, the 3rd edition of the Wechsler Intelligence Scale for Children (WISC-III) was criticized for not evaluating important areas such as fluid intelligence (*Gf*), long-term memory storage and retrieval (*Glr*), and auditory processing (*Ga*), as well as for having a confusing group called Resistance to Distraction, which was called into question regarding its existence as cognitive factor (Flanagan, McGrew, & Ortiz, 2000).

It is important to highlight that, to assess capacities (second stratum), the psychological tool must offer items for the respondent to demonstrate determined abilities (third stratum). Thus, to evaluate fluid reasoning (*Gf*) in a broad sense, items are required to investigate the abilities induction, general sequential reasoning and quantitative reasoning. In the event that an instrument assesses only one or two of these skills, there must be specification of which are being measured. Thus, in the WISC, capacities are the indexes and abilities are the subtests (grouping of items).

In the 4th edition of WISC significant modifications were made to the instrument's structure and in the redefinition of evaluated capacities. Three subtests were eliminated; Picture Arrangement, Object Assembly, and Mazes, while the subtests of Letter-Number Sequencing, Matrix Reasoning, Word Reasoning, Picture Concepts, and Cancellation were introduced.

The Resistance to Distraction Index was replaced with Working Memory Index (WMI), being evaluated by the subtests Digit Span and Letter-Number Sequencing, with Arithmetic as an additional subtest. The Verbal Comprehension Index (VCI) is evaluated by the subtests Similarities, Vocabulary, and Comprehension, with additional subtests Information and Word Reasoning. The Perceptual Organization factor index became the Perceptual Reasoning Index (PRI) and is evaluated by the Block Design, Matrix Reasoning and Picture Concepts subtests, with Picture Completion as a supplementary subtest. Finally, the Processing Speed Index (PSI) had no modifications, being evaluated by Coding and Symbol Search (Kaufman, Flanagan, Alfonso, & Mascolo, 2006). Table 1 shows the possible relationships between the subtests and indexes of the WISC-IV and the abilities and capacities proposed in the CHC model. The information was taken from the work of Flanagan, Ortiz and Alfonso (2013, in Flanagan, Alfonso, & Reynolds, 2013).

TABLE 1
Relations between the WISC-and the CHC model

<i>WISC-IV</i>	<i>CHC</i>
Working Memory (I)	Short-term Memory (C)
Digit Span	Short-term Memory (H) and Operational Memory (H)
Letter-Number Sequencing	Operational Memory (H)
Arithmetic	Operational Memory (H) and Quantitative Reasoning (H)
Verbal Comprehension (I)	Crystallized Intelligence (<i>Gc</i>)
Similarities	Lexical Knowledge and Induction (H)
Comprehension	General Knowledge (verbal) (H)
Vocabulary	Lexical Knowledge (H)
Information	General Knowledge (verbal) (H)
Word Reasoning	Lexical Knowledge and Induction (H)
Perceptual Reasoning (I)	Fluid Intelligence (C) and Visual Processing (C)
Block Design	Visualization (H)
Matrix Reasoning	Induction (H)
Picture Concepts	Induction (H)
Picture Completion	Closure Flexibility (H) and General Knowledge (verbal) (H)
Processing Speed (I)	Cognitive Speed (C)
Coding	Rhythm (speed and fluency) of test completion (H)
Symbol Search	Perceptual Speed (H)

Note: (I) WISC-IV Index, (C) CHC model capacity (H) CHC model ability.

International studies have sought to investigate the correlation between the WISC-IV and the CHC model as identified in the table above, and these studies tend to

support this classification (Chen, Keith, Chen, & Chang, 2009; Lecerf, Rossier, Favez, Revert, & Coleaux, 2010). In Brazil, researchers Rueda, Sisto, Santos, Noronha and Castro (2012) have been conducting studies with the WISC-IV, contributing to the validation process in applying the scale in the Brazilian context. In seeking validity evidence based on the internal structure by means of factor analysis, the authors found that the subtests were grouped in the four established indexes. Thus, it seems to clearly indicate that the instrument as a whole assesses the capacities and abilities proposed by the scale. This data also suggests that the structure of the WISC-IV found in the Brazilian population tends to corroborate the CHC model. However more studies in Brazil are needed in order to confirm how the indexes and subtests of the WISC-IV are associated with the capacities and abilities proposed in the CHC model, just as more validity evidence is needed based on the relationship with external variables to the WISC-IV. Thus, the objective of this study was to verify the WISC-IV's relationship with the Cloze Test, widely used to assess reading comprehension.

Considering the intelligence construct, the WISC-IV's object of evaluation, there has been consensus among researchers regarding the existence of the relationship between cognition and reading comprehension. According to Sternberg (2000), reading comprehension involves a verbal cognitive ability that begins when the player makes contact with new content. Initially, the working memory is activated to capture textual information and, then, analogies are made to information already stored in long-term memory. The reader then goes on to understand the new information that will be archived, waiting for some opportunity to be accessed.

The Cloze Test has been the subject of study among researchers, which has shown the association of cognitive abilities and reading comprehension. For Santos (2005), this instrument inherently assumes that reading comprehension is a result of cognitive processes including decoding symbols, the perception of clues in the text, and the recovery of prior knowledge in memory.

Some research has employed WISC-III subtests and the Cloze Test as intelligence assessment tools, such as the study of Mota et al (2009), which sought associations between phonological processing, measured by subtests Digit Span and Vocabulary in the WISC-III, with the Cloze scores. The results indicated significant correlations between Cloze and the Digit Span subtest, but there were no significant indices found between Cloze and the Vocabulary subtest. The study by Joly and Istome (2008), showed high and significant

correlations between scores with the Cloze and Verbal IQ, Total, Verbal Comprehension and Resistance to Distraction. The authors point out that verbal abilities are specific cognitive skills of reading comprehension and resistance to distraction is related to attention, which in turn is basic to learning. There were also high and moderate correlations with Execution IQ and Perceptual Organization. The authors also highlight the importance of implementing execution and spatial skills in reading comprehension.

The study of Santos, Sisto and Noronha (2010), sought to associate the results of Cloze testing, which involves linguistic abilities, with nonverbal intelligence measures using the TONI-3 – Form A. The correlation indices show the existence of the relationship between intelligence and reading comprehension variables, revealing that intelligence can predict ease in acquiring other behaviors, especially those related to school performance such as reading comprehension.

In the study by Vanderwood, McGrew, Flanagan and Keith (2002), the Woodcock-Johnson Psycho-educational Battery-Revised (WJ-R), an instrument based on Cattell-Horn-Carroll's theory of cognitive capacities, was used to analyze the contribution of specific cognitive abilities to the realization of reading. The data were analyzed by Structural Equation Modeling (SEM), with calibration and cross-validation of samples, of four different relational models of hypothesized variables, to determine if specific abilities can provide relevant information on the development of reading skills. The results indicate that crystallized intelligence (*Gc*) and auditory processing (*Ga*) play an important role in the development of reading skills.

The more similar the cognitive demands required for realization of items/tasks, the greater the relationship between two instruments. Thus, it is expected that the Cloze Test is more positively correlated with the Verbal Comprehension Index of the WISC-IV, as the index that tends to evaluate reading comprehension specifically. Table 1 illustrates that the cognitive abilities demanded by the VCI tasks are lexical knowledge, induction and general verbal comprehension, that is, to know words, semantics and to know to reason inductively (seek similarities and differences) among them. In the Cloze Test the individual reads a short story with missing words, so that in addition to knowing how to read, one must understand the words and semantics to understanding the story and also to infer more easily what word is missing that fits into the context. Except the ability of induction, the others are described as part of the comprehension-knowledge (crystallized intelligence) capacity of the CHC model. Other correlations that might occur, as observed in the

above-referenced studies on the Cloze Test analysis combined with the WISC-III, must be understood from the cognitive abilities that each type of task demands.

The objective of the study is not restricted to verifying the relationship of the WISC-IV with the Cloze Test in general, but also to analyze the possible associations between factor indexes of the WISC-IV and the Cloze Test, founded on the cognitive abilities according to the CHC model. This will enable a better understanding of why there are associations between tests, and will investigate the adequacy of the WISC-IV in assessing reading comprehension, as proposed by the CHC model, since the Cloze Test is specific to that capacity.

Method

Participants

A total of 150 children were evaluated, ages 6 to 14 years, in the 1st through 9th grades of a single elementary school. Of the selected sample, 60 children were between 6 and 9 years old ($M=8$; $DP=1,039$) and were in 1st through 4th grades; 60% were female ($n=36$) and 40% male ($n=24$), 8.3% attended 1st grade, 21.7%, 2nd, 21.7%, 3rd, and, lastly, 48.3% were in the 4th grade. Between the ages of 10 to 14 years, 90 children participated ($M=11.3$; $DP=1.12$), with 55.6% female, 33.3% in the 5th grade; 20%, 6th; 32.2% in 7th; 11% in 8th, and 2% were in 9th grade.

Instruments

WISC-IV Wechsler Intelligence Scale for Children-4th edition (Rueda, Sisto, Santos, Noronha, & Castro, 2012)

The fourth edition of WISC replaces the 1991 edited version in the United States and adaptation studies have sought validity evidence to the Brazilian context.

The instrument evaluates the intelligence of children age 6 to 15 years, and results are expressed in four factor indexes and obtained based on scores of 15 subtests. The Working Memory Index (WMI) is evaluated by the subtests Digit Span, Letter-Number Sequencing and Arithmetic. The Perceptual Reasoning Index (PRI) is evaluated by the Block Design, Matrix Reasoning, and Picture Concepts subtests. The Verbal Comprehension Index (VCI) is evaluated by subtests Similarities, Comprehension, Vocabulary, Information and Word Reasoning. Finally, the Coding, Symbol Search, and Cancellation measure the Processing Speed Index (PSI).

Cloze Test

The Cloze Test is an instrument that has been widely used to assess reading comprehension level. It was created by Taylor in 1953 and consists of adapting a text by omitting some of its words, replacing them with blanks that should be the length of the omitted word. The reader is asked, after reading the text, to complete the blank spaces with the word deemed most appropriate. As the sample of this study involved children from the 1st through 9th grade of elementary school, we used two texts for the Cloze test, according to age group. Every 5th word was omitted from the text, being replaced by a line of proportional size to the excluded word. One point was awarded for each correct word placement.

To assess children from 6th through 9th grade, the text "Nature of Things" by Santos (2005) was used, which contains 250 words and 40 blanks. Therefore, scores can range from 0 to 40 points. This test has validity evidence of criteria, as differentiated by students' grade level, that is, the more advanced the grade level, the higher the average score. In the study by Oliveira, Boruchovitch and Santos (2008), in which the same text was used, women obtained higher averages than men and the highest scores were those of older students, higher grade levels, and from private schools.

To assess the reading comprehension of children in the 1st through 4th grades, the text "An Unhappy Vengeance" by Santos (2005) was used, with 85 words and 15 blanks. Accordingly, scores for this text can range from 0 to 15 points. The study of Santos and Oliveira (2010) sought to investigate the adequacy of the Cloze technique using a reading intervention program, and the results showed good psychometric properties.

Data Analysis Procedures

The data were analyzed according to descriptive and inferential statistics. The means and standard deviations of the two instruments used were established. In order to verify validity evidence through relationship with results of tests that assess related constructs, we used the statistical technique Structural Equation Modeling, through the Analysis of Moment Structures program (AMOS). The Maximum Likelihood (ML) method was used for model estimation. As for the adjustment ratios, the chi-square of the (χ^2) and the degrees of freedom (df), the ratio of chi-square to degrees of freedom (χ^2/df), the Goodness-of-Fit Index (GFI), the Adjusted Goodness-of-Fit Index (AGFI), the Comparative Fit Index (CFI), the Root-Mean-Square Error of Approximation (RMSEA) and Standardized Root Mean Square Residual (SRMR) were considered.

The chi-square (χ^2) verifies the likelihood of the theoretical model fit to the data found, and the higher the value, the worse the fit. Thus, values between 2 and 3 are recommended as a good fit. The values of GFI and AGFI indicate the proportion of variance-covariance in the data and must be greater than or equal to 0.90. The CFI compares the model covariance matrix with that actually observed, also with a values equal to or greater than 0.90 recommended. The RMSEA value with 90% confidence interval (IC90%) must be between 0.05

and 0.08, assuming values up to 0.10. Elevated indices show how poor the fit is. For SRMR, fit values below 0.80 are considered quality indicators (Hair, Anderson, Tatham, & Black, 2009).

Results

Descriptive statistics of the instruments and the correlations between the factors are shown in **Table 2**.

TABLE 2
Estimates for the variables

	<i>Standardized Coefficient (β)</i>	<i>Coefficient</i>	<i>SE</i>	<i>CR</i>	<i>p</i>
Cloze-Processing Speed	.206	.597	.303	1.971	.049
Cloze-Verbal Comprehension	.601	2.263	.653	3.467	***
Cloze-Operational Memory	.092	.214	.472	.452	.651

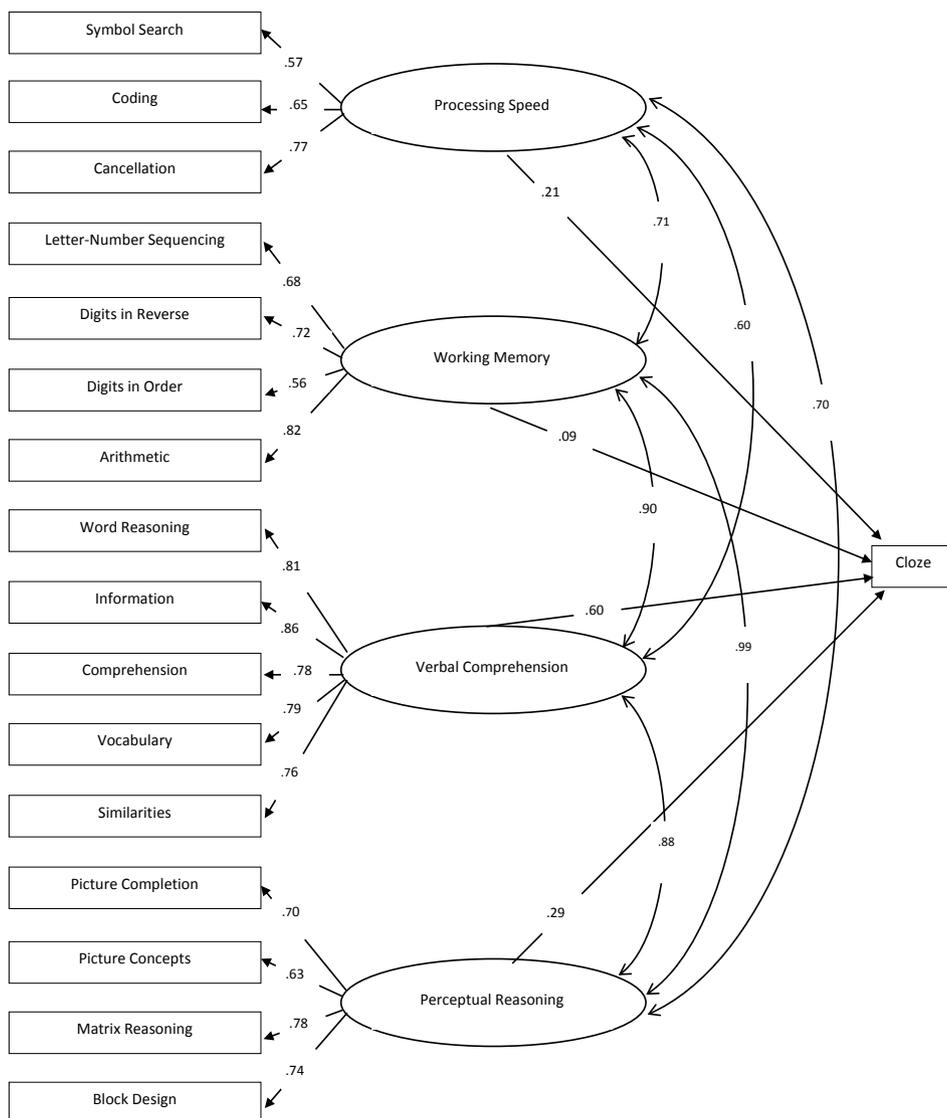


Figure 1. Structural model of the relationship between the WISC-IV and the Cloze Test

As can be observed in **Table 2**, within the WISC-IV subtest correlations, the greatest positive index was between the subtests Similarities and Information ($r=0.54$). There were no significant negative correlations and there were no significant correlations between some subtests. Regarding the association between the WISC-IV subtests with the Cloze Test, no significant correlations were presented by the subtests Coding, Symbol Search and Cancellation. With the other subtests, there were significant positive correlations with low magnitudes (Block Design, $r=0.32$; Letter-Number Sequencing, $r=0.32$; Comprehension, $r=0.36$; Similarities, $r=0.37$; and Picture Completion, $r=0.37$), and moderate magnitudes (Arithmetic, $r=0.41$; Matrix Reasoning, $r=0.44$; Vocabulary, $r=0.45$; Word Reasoning, $r=0.45$; Picture Concepts, $r=0.46$; and Information, $r=0.59$).

After exploring the correlation indices between the WISC-IV subtests and the Cloze Test, the regression estimates for the four factor indexes of the WISC-IV, considered as latent variables, were verified in relation to the score obtained in the Cloze Test, according to the model presented in **Figure 1**, *back of*. Initially, the four factor indexes were inserted in the model as predictors of the Cloze, however, there were no significant relationships found, which may be explained by the high correlation between the indexes themselves (see **Figure 1**). Thus, it was decided to exclude the line that indicated

the association of Cloze with the Perceptual Reasoning Index, since this would be the index bearing the lowest theoretical relation with the reading comprehension. In this way, the results showed good fit indices: $\chi^2(111)=136.427$, $p<0.001$, $\chi^2/df=1.229$, GFI=0.910, AGFI=0.875, CFI=0.982, RMSEA=0.039 (IC90%=0.00 to 0.059), SRMR=0.0468 (**Table 3**).

In accordance with expectation, the factor index with the greatest predictive power relative to reading comprehension is Verbal Comprehension, followed by Processing Speed and Operational Memory. The explained variance of the Cloze was 0.69, that is, 69% of the variability of the scores obtained in the Cloze test are explained by the factor indexes Verbal Comprehension and Processing Speed. This means that the level of reading comprehension evaluated by the Cloze depends, in part, on verbal cognition and information processing speed.

Discussion

This study aimed to search for validity evidence for the WISC-IV through the relationship with external variables from the association of subtests and factor indexes with the reading comprehension measured by the Cloze Test. Initially, correlational bivariate analyses were performed with the Pearson correlation method, to observe relationships between WISC-IV subtests. This procedure is important because the factor indices

TABLE 3
Pearson's correlation analysis between the WISC-IV subtests and the Cloze Test

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Cloze	1	.32**	.37**	.35**	.46**	.06	.45**	.32**	.44**	.36**	.19	.37**	.17	.59**	.41**	.45**
Block Design		1	.30**	.31**	.24*	.21*	.21*	.36**	.38**	.16	.22*	.45**	.15	.30**	.36**	.18
Similarities			1	.37**	.36**	.06	.45**	.32**	.37**	.46**	.21*	.25*	.53	.54**	.47**	.45**
Digit Span				1	.24*	.93	.30**	.22*	.38**	.27**	-.13	.20*	.08	.36**	.33**	.28**
Picture Concepts					1	.10	.10	.27**	.36**	.24*	.09	.28**	.06	.29**	.43**	.22*
Coding						1	-.03	.27**	.30**	-.05	.46**	.16	.46**	.03	.20*	.03
Vocabulary							1	.18	.25*	.54**	-.01	.29**	.02	.42**	.17	.45**
Letter-Number Sequencing								1	.47**	.04	.21*	.37**	.21*	.26*	.36**	.23*
Matrix Reasoning									1	.17	.19	.29**	.21*	.36**	.45**	.34**
Comprehension										1	-.08	.21*	.00	.37**	.11	.39**
Symbol Search											1	.16	.31**	.19	.27**	.06
Picture Completion												1	.15	.30**	.28**	.38**
Cancelling													1	.07	.17	.09
Information														1	.48**	.42**
Arithmetic															1	.22*
Word Reasoning																1

* $p<.05$; ** $p<.01$.

used in structural equation modeling are a composition of the sum of subtests. Given this, it is expected that the tasks that make up a particular index are correlated amongst themselves.

The results indicated that the subtests Comprehension (general verbal comprehension ability in the CHC model) and Vocabulary (lexical knowledge ability in the CHC model) had the highest positive correlation, which can be explained by the similarity between tasks. In Comprehension, one is asked to say what he/she would do in a given situation, and in Vocabulary, one must explain objects and their semantics. To perform well in Comprehension, one must know semantically what objects are and the purpose they serve. For example, a fictional item in Comprehension might be: "What do you do if you see the garden catch fire?" The respondent would need to understand what fire and a garden are, what a hose is, a phone, and other objects that could help in this situation.

The two referenced subtests belong to the Verbal Comprehension Index (VCI), and all subtests of this index are correlated with each other significantly and positively with moderate magnitude. This suggests robustness to the index, consisting of tasks that require skills usually associated with Verbal Comprehension and which are similar in format and content. An analysis of **Table 1** identifies abilities in the CHC model, which tend to be required in the VCI subtests, similar to the CHC capacity Comprehension-Knowledge (crystallized intelligence). All of the skills measured by the VCI are important for a better verbal comprehension (lexical knowledge, general knowledge and verbal induction).

Regarding the other indexes it can be noted, in **Table 2**, that their subtests obtained significant and positive correlations. Specifically referring to Working Memory Index, the correlations were of low magnitude. In the Processing Speed Index, only the Symbol Search and Cancellation subtests presented low magnitude, whereas the others were moderate. In the Perceptual Reasoning Index (PRI), only one correlation showed moderate magnitude and the others were low.

Importantly, low correlations between the subtests do not necessarily mean an undesirable outcome because, as proposed in the CHC model, a strong correlation between the subtest Matrix Reasoning and Picture Completions, in the PRI for example, is not expected. As observed in **Table 1**, one has greater proximity to the visual processing capability (CHC), which depends on the ability to visualize, and the other is more attached fluid intelligence (CHC), as it measures induction ability. However, they still correlate because in visualization tasks, inductive reasoning is

also present, as can be seen in Block Design: in the evaluation of the visuospatial reasoning (Rueda & Muniz, 2012).

Returning to the study's primary objective of investigating the relationship between the WISC-IV and the Cloze Test, it is important to look for identified bivariate correlations. It is noteworthy that the correlation between the Cloze Test and subtest Digit Span is in agreement with the results of Brazilian studies such as Mota et al (2009), and Joly and Istome (2008). This result also supports the foreign literature on the subject, because as stated by Sternberg (2000), reading comprehension involves the activation of operational memory, which is the cognitive ability assessed by subtest Digit Span.

Moderate correlations between the Cloze and cognitive verbal abilities assessed by the subtests Information, Comprehension, Vocabulary, Similarities, and Word Reasoning reveal the strong association of reading comprehension with crystallized intelligence (*Gc*). Consequently, they demonstrate that the Cloze Test can predict these abilities, as revealed in the national study by Joly and Istome (2008), as well as those of foreign scholars who have traditionally investigated the subject, such as Ackerman, Beier and Bowen (2000), and Vanderwood, McGrew, Flanagan and Keith (2002). The results obtained herein also tend to reinforce VCI as an important variable that evaluates the capacity of Comprehension-Knowledge (crystallized intelligence), proposed in the CHC model, as can be seen in Table 1 and that is the understanding described in scientific articles (Chen et al, 2009; Flanagan, Alfonso, & Reynolds, 2013; Lecerf et al, 2010).

On the correlations with the Cloze Test, moderate magnitude values are observed with the Arithmetic subtest, which belongs to the Working Memory Index (WMI). In the earlier version of the WISC, the III (Wechsler, 1991), Arithmetic was part of the Verbal Intellectual Quotient, understood as more related to crystallized intelligence. There have been criticisms regarding this composition, since such a subtest would be associated with quantitative reasoning (Keith & Reynolds, 2010), an ability present in fluid intelligence (Schneider & McGrew, 2012). In the new version (WISC-IV) the subtest was entered in the WMI.

For good performance in this subtest, in addition to quantitative reasoning skills and working (operational) memory, it is important that one is able to understand written and spoken texts, as well as knowledge of arithmetic operations such as addition, subtraction, division, multiplication, fractions, and percentages, and all of this knowledge is related to the ability of Comprehension-Knowledge (crystallized intelligence).

Specifically, with the Cloze Test, the correlation seems to have occurred because both tests require the ability to understand texts for the task to be performed successfully.

The structural equation modeling revealed that the factor indexes are strongly associated with each other, such as Verbal Comprehension (VCI) and Working Memory (WMI) with a value of .90, interfering in the association of the latter with the Cloze, which would be expected, due to the positive correlations of the subtests Digit Span ($r=.35$), Letter-Number Sequencing ($r=.32$), and Arithmetic ($r=.41$) with reading comprehension. As noted earlier with respect to the WISC-IV VCI subtests and the abilities measured by them, the result between this index and the Cloze Test corroborates the understanding of how general verbal knowledge, lexical knowledge, and induction skills are important for good performance in reading comprehension. The results that correspond to the Working Memory Index also point to the importance of working memory skills, short-term memory and written language comprehension, so that the respondent can successfully carry out the Cloze Test.

The high correlation between the Working Memory and Verbal Comprehension, and Working Memory and Perceptual Reasoning indexes points to a possible overlapping of factors, thus indicating a simpler explanation for theories that address intelligence capacities, such as the CHC model. However, when verifying the correlation between the subtests (WISC-IV tasks), among the factors that showed a high relation between them, there are significant, low positive and some moderate magnitudes observed. In addition, the task content of factors that seem to overlap are also very different, some even requiring semantic knowledge, reading ability and, others, without demanding these types of knowledge or abilities. Moreover, in the WISC-IV manual adapted for Brazil, no such overlaps were observed. Therefore, it is important that studies be designed to investigate this possible overlap between the factors to formulate a more sustained position on this phenomenon. Finally, even if overlaps in such latent factors are detected in future research, it is important to maintain the separation, since the content evaluated is very different and, more important than observing a factor composed of several abilities, is to observe each of the abilities which are measured by different tasks and that really contribute to a better understanding of the difficulties and facilities of cognitive demands.

It is noteworthy that the Processing Speed Index (PSI) was considered a significant predictor of reading comprehension, despite its subtests Coding ($r=.06$),

Symbol Search ($r=.19$), and Cancellation ($r=.17$) not bearing any significant correlations with the Cloze Test. This index is associated with operational memory (.71) and verbal comprehension (.60), which in turn is strongly associated with reading comprehension. Theoretically the association is explained by the demands of cognitive abilities of the tasks of this index. In Table 2 we can verify that Coding is related to the Rhythm of test, and Symbol Search with Processing Speed, both abilities that measure the capacity of Cognitive Speed in the CHC model.

The results show that the greatest association was between the VCI and the Cloze Test. However, other associations were also found. In the present discussion, we tried to go beyond simply commenting on the correlations, trying to understand the theoretical reason they occur. In this sense, the CHC model has contributed to the relationship between variables being understood by their abilities and capacities, that is, from the cognitive demands proposed in the tasks.

Considering the need for psychological instruments that evaluate intelligence in a multidimensional way, new research must be carried out with a view to find associations between cognitive variables and the factors of the CHC model. The contribution of the present study is to demonstrate the strong association of the Verbal Comprehension Index with reading comprehension, emphasizing that crystallized intelligence is currently being named Comprehension-Knowledge. It is important to remember that this ability involves knowledge and content dependent on the educational experience.

Another relevant aspect to be highlighted is that the results obtained herein amplify the perspective of using the Cloze Test, given the association that it has with the indexes measured in the WISC-IV. Its great advantage is that it is a measure of easy elaboration and quite accessible to be used in the classroom routine. However, the study is not free of limitations, one of the main ones being the fact that the Cloze stories were not the same for the whole sample, with differences in the number of gaps between the measures applied. In future studies, keeping the Cloze as a measure of comprehension implies that there would be an equalizing of different texts that can be used with participants of different levels of schooling like those in the present study.

In terms of the future research agenda, it would be opportune to consider the use of other measures of reading comprehension, one of them including open-ended questions about the text. Moreover, intelligence could also be measured with other instruments that evaluate fluid intelligence (Gf) that

are associated with other factor indexes that were not the target of this study, such as perceptual reasoning, for example.

Finally, by indicating the high association between crystallized cognitive abilities and reading comprehension, the results reveal validity evidence favorable to the interpretations provided by WISC-IV, helping to bring it closer to more contemporary

instruments in the evaluation of intelligence as proposed by the CHC model. Research for this purpose contributes to the practice of intelligence evaluation by providing elements that ensure the interpretation quality of the test scores obtained and, at the same time, can support interventions in the educational context and research aimed at investigating student reading performance.

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