Avaliação Psicológica
ISSN 2175-3431 (versão on-line)

Validity evidence for the Neuropsychological Test for the Assessment of Visuospatial Binding: a working memory test

Yuri E. G. Santana, *Jonatas R. Bessa*, *Marian A. A. Abbas*
Universidade Federal da Bahia, Salvador-BA, Brasil
Camilla O. S. Barretto, *Milena F. Ramos*
Centro Universitário Uninassau, Salvador-BA, Brasil
Neander Abreu[1]
Universidade Federal da Bahia, Salvador-BA, Brasil

ABSTRACT

The Neuropsychological Test for the Assessment of Visuospatial Binding (TNABV) was developed to measure the Working Memory binding for object-location features. This study aimed to provide validity evidence related to the content and internal structure of the TNABV. To investigate the evidence based on internal structure, the sample was composed of 1173 people. Participants were between 18 and 95 years of age. In order to investigate the content-related validity evidence, a judgment was performed through the analysis of seven experts. The data analysis was carried out through exploratory factor analysis, the Internal Consistency Content Validity Index (CVI). The result suggested a one-dimensional model with an explained variation of 41.78% and Cronbach's alpha of .82. The total CVI showed an agreement of .98. The findings indicated that the psychometric properties evaluated in the TNABV are adequate.
Keywords: working memory; neuropsychological assessment; test validity; factor analysis; test reliability.

RESUMO – Evidências de Validade do Teste Neuropsicológico para Avaliação do *Binding* Visuoespacial: Um Teste de Memória Operacional

O Teste Neuropsicológico para Avaliação do *Binding* Visuoespacial (TNABV) foi desenvolvido para avaliar o *binding* da memória operacional para os recursos de objeto-localização. Este estudo investigou as evidências de validade relacionadas ao conteúdo e estrutura interna do TNABV. Para realizar as evidências baseadas na estrutura interna, a amostra foi composta por 1173 pessoas. Os participantes tinham entre 18 e 95 anos. Para investigar a validade das evidências baseadas no conteúdo, foi realizado um julgamento pela análise de sete especialistas. A análise dos dados foi realizada por meio de análise fatorial exploratória, Índice de Confiabilidade e Validade de Conteúdo (IVC). O resultado sugeriu um modelo unidimensional com uma variação explicada de 41,78% e o alfa de Cronbach de 0,82. O IVC total mostrou uma concordância de 0,98. Os achados indicaram que as propriedades psicométricas avaliadas no TNABV são adequadas.
Palavras-chave: memória operacional; avaliação neuropsicológica; validade de teste; análise fatorial; confiabilidade de teste.

RESUMEN – Evidencias de validez del Test Neuropsicológico para la Evaluación de *Binding* Visuoespacial: un test de memoria operativa

El Test Neuropsicológico para la Evaluación de *Binding* Visuoespacial (TNABV) se desarrolló para evaluar el *binding* de la memoria operativa para los recursos de objeto-localización. Este estudio investigó las evidencias de validez relacionadas con el contenido y la estructura interna del TNABV. Para explorar las evidencias basadas en la estructura interna, la muestra se compuso por 1173 personas. Los participantes tenían entre 18 y 95 años. Para investigar la validez de las evidencias basadas en el contenido se realizó un juicio mediante la revisión de siete expertos. El análisis de los datos se ejecutó utilizando el análisis factorial exploratorio, el Índice de Confiabilidad y la Validez de Contenido (CVI). El resultado sugirió un modelo unidimensional con una variación explicada del 41,78% y un alfa de Cronbach de 0.82. El CVI total mostró una concordancia de 0,98. Los hallazgos indicaron que las propiedades psicométricas evaluadas en el TNABV son adecuadas.
Palabras clave: memoria operativa; evaluación neuropsicológica; validez del test; análisis factorial; confiabilidad del test.

Working Memory (WM) is the system responsible for storing, processing and manipulating information for a limited time (Baddeley, 2012). This system is divided into four subsystems: the central executive, responsible for attentional control; the phonological loop, involved in verbal information maintenance during a task; the visuospatial sketchpad, which performs the manipulation of visual information; and the episodic buffer. The episodic buffer is characterized as a component with the ability to integrate information from different sources into multidimensional codes from external stimuli and the information from long-term memory (Baddeley, 2012; Hitch et al., 2020).

[1] Endereço para correspondência: Laboratório de Neuropsicologia Clínica e Cognitiva. Instituto de Psicologia. Rua Professor Aristídes Novis, 197, Federação, 40210-630, Salvador - BA. Tel.: (71) 3283-6474. *E-mail:* neandersa@hotmail.com

The episodic buffer may play a role through a cognitive process called binding (Baddeley, 2012; Hitch et al., 2020). Binding is the cognitive process of temporarily sustaining a connection between information of similar or different features. It happens, for example, in everyday life when we need to remember where an object was stored or remember someone's name when we recognize his/her face or hear his/her voice.

Deficits in WM are common in clinical disorders, which may imply functional impairments in daily life. Studies suggest that impairments in this function may be related to Alzheimer's disease and mild cognitive impairment (Goodman et al., 2018), schizophrenia, schizoaffective disorder, bipolar disorder (Gold et al., 2018), attention deficit hyperactivity disorder, specific learning disorders (Maehler & Schuchardt, 2016) and traumatic brain injury (Dunning et al., 2016).

There are many tests and tasks which evaluate the different processes of working memory. The majority of them are focused specifically on visual-spatial sketchpad and phonological loop, as example: corsi tapping blocks task, digit span task, letter-number sequencing, arithmetics (Lezak, 2014). The international literature presents a limitation of a clinical test which assesses this binding process, because it is more common to develop an experiment task without the investigation of the validity evidence (Abreu et al., 2018). However, there are some binding tasks to evaluate this process, such as: memory binding test - MBT (Gramunt, 2016), which presented a reliability range from .64 to .76, and visual short-term memory binding test - VSTMB, with 77% sensitivity and 83% specificity to identify cases of Alzheimer's disease. (Parra et al., 2010). However, these tests do not simulate a daily scene in its execution. Similarly, in Brazilian context, there are still no validated and reliable clinical instruments for assessing the visuospatial WM binding of object-location, which brings relevance to studies of psychometric validity and standardization for the Brazilian population (satepsi.cfp.org.br). In view of this gap and the need for a better understanding of the functioning of the visuospatial WM binding object-location, we developed the software of the Neuropsychological Test for the Assessment of Visuospatial Binding (TNABV). The TNABV is a computerized task and has the proposal of evaluating the visuospatial binding process that occurred in the WM episodic buffer, more specifically, it was made to evaluate the binding of the visual component (objects) and spatial (location) information simulating a daily scene and its execution (Abreu et al., 2018). The use of instruments with ecological characteristics can contribute to the neuropsychological assessment. Robert and Schmitter-Edgecombe (2016) suggest that the individual's performance assessed under these conditions may be closer to reality. The development of an instrument that measures visuospatial bindings aims to contribute to the neuropsychological clinic and research settings. To make it useful is also crucial to test its reliability. The TNABV is proposed to be a test with ecological characteristics, i.e., simulates a daily scene, which can bring more precision, presenting a measure closer to reality (Robertson & Schmitter-Edgecombe, 2016). Another aspect to be studied is the possible proportional relations that the visuospatial binding can have with other cognitive processes resulting from WM operation. This would help studies of the WM model, as well as the use of more efficient neuropsychological interventions and rehabilitation processes.Despite the development of the software TNABV, this test had a lack of validity evidence based on its content, internal structure and measures of reliability (Abreu et al., 2018).

The present study had the proposal to analyze evidence of validity of a test, which simulates a daily scene that measures the visuospatial binding of WM. The Psychometric validity evidence based on content and internal structure of the TNABV were verified, using expert judgments and an exploratory factor analysis. The results of expert judgments were then analyzed using the Content Validity Index. This is one measurement model in which a group of experts agrees on the relevance of items making up a measure. In this study, the CVI was calculated as an item-level content validity index and a scale-level content validity index. The second aim was to observe the factor structure of the instrument, analyzing whether there is a structure based on the theoretical model, the reliability of the instrument and whether there is any problematic item that needs to be excluded.

Method

Type of the Study

This is an exploratory and psychometric study conducted in brazilian sample and it was divided in two parts intending to provide evidence of validity based on content and internal structure and reliability of the TNABV. The study 1, relating to the validity evidence based on the content of the test, had a sample composed by seven expert participants (n=7). Further, the study 2 had 1173 participants on a sample, allowing the investigation of the internal structure and reliability of the test.

Participants

Study 1: Evidence based on test content

To investigate the validity evidence based on the content, we selected experts' judgment procedures. Seven Brazilian participants with expertise in the area of neuropsychology, with a minimum of five years of experience, were invited to be part of this study. It should be noted that everyone accepted the invitation and this sample was selected for convenience. All members have been involved in the development of neuropsychological tests and research in the field of cognition. This choice procedure is in accordance with the guidelines suggested in the literature (Alexandre & Coluci 2011). All of the experts were certified with an academic level graduate title. Two of them had a doctorate; two had a master's degree; and three had a postgraduate degree in Neuropsychology or Neuroscience.

Study 2: Evidence base on internal structure

To perform the exploratory factor analysis, a non-probabilistic sample of 1173 people residents in the state of Bahia-Brazil was recruited, 720 were female (61.38%). Participants were selected from universities, churches and community centers for convenience. The sample showed an age range between 18 and 95 years (M=41.95 years; SD=20.05). The inclusion criterion was to be at least 18 years old and have no history of neurological disorder.

Instruments

Content Validity Index Scale. For the expert's judgment procedure, a content validity questionnaire was developed and sent to the experts. After they answered, we calculated the agreement coefficient. This scale had five objective statements for which the answers followed a Likert scale of 4 points, being: 1. I do not agree, 2. Indifferent, 3. I partially agree, and 4. I strongly agree. The five objective statements were: (a) the TNABV assesses visuospatial memory; (b) the test assesses the visuospatial WM; (c) based on the Baddeley and Hitch (1974) Multicomponent Model of Operational Memory and its revision in 2000 the test evaluates the visuospatial sketchpad component; (d) based on Baddeley's Multicomponent Operating Memory Model (2012), the test evaluates the binding in visuospatial memory; and (e) the test presents items (figures) that are easily recognized for adults and elderly examinees. Below each statement, there was a space for writing suggestions and observations about the test or changes that should be made due to difficulties in one or more items required to be analyzed. This questionnaire aimed to assess the adequacy of the test to the theoretical model and the test format/design.

The Neuropsychological Test for the Assessment of Visuospatial Binding. The TNABV is a computerized test and was developed to be self-applied, simulating the context of a kitchen, in which there are 16 cabinet doors, four doors at each end of the screen (Abreu et al., 2018). The individual must start the test by pressing the "start" button, after reading the initial instructions: "Pay attention to this object and which door it goes in. You have to remember which object and door it goes in". At the beginning of the test, objects related to the environment (food and cooking utensils) are presented in sequence in the center of the screen, and these are subsequently stored in one of the cabinet doors. The objects and their respective locations must be memorized and subsequently evoked (Figure 1). After a one-second interval with a blank screen, the image of the kitchen is again presented with some objects in the center of the screen. The examinee must select the previously presented objects and allocate them in the previously established locations (doors) – there is no limited time for this evocation process.

The objects are presented in three sequences of 3, 4 and 5 items. The objects in the center of the screen are always twice the number of objects allocated.

The first sequence has three objects that are placed into the doorsand and, after the first second interval, six objects are displayed to the examiner (Figure 1). Then, the examinee should choose the cabinet door and place the object there. In the remaining sequences, four allocated objects are shown and eight are displayed in the center of the screen, and subsequently, five objects are allocated and 10 are displayed in the post-allocation.

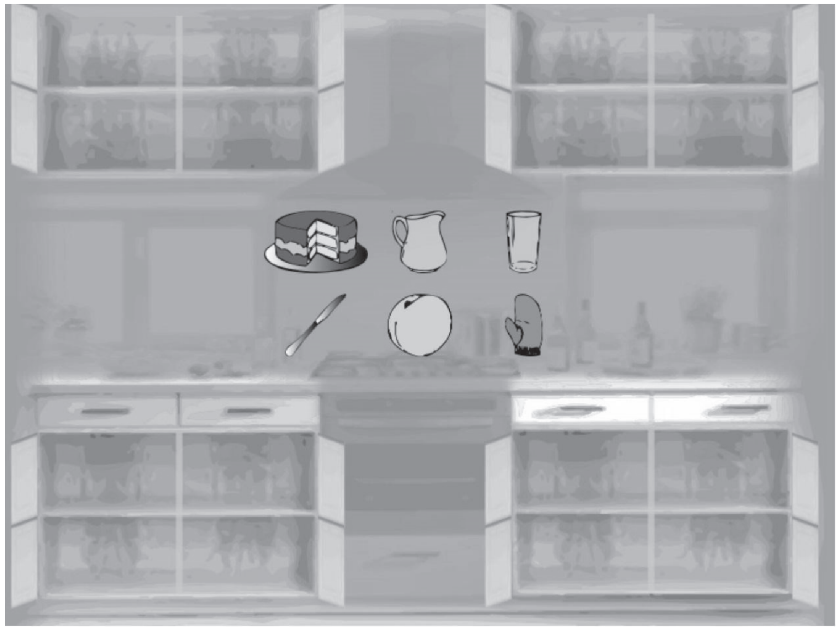
The TNABV generates an efficacy index of visuospatial bindings for 3, 4 and 5 trials. The TNABV's efficacy index is calculated by the span of the sequence trial times the total of correct bindings by span sequence. All instructions from TNABV are presented in the test, which may be self-administered or can be guided by the examiner.

In this study, the examiners guided all tests, since some participants declared they were not familiar with computers. Therefore, we decided to standardize the examiner's assistance through the manipulation of the mouse, as soon as the participant chose the objects and doors where they should be placed. An exploratory factor analysis was performed with the results of this instrument.

Procedures

With the approval of the Research Ethics Committee of the Institute of Psychology (CAAE: 89544618.7.0000.5686), of the Federal University of Bahia (UFBA), the study was completed in accordance with the Helsinki Declaration.

Figure 1
Representation of the Wardrobe Arrangement Test after the Automatic Allocation of Items by the Instrument



Study 1

For the expert judgment stage, seven participants were chosen and invited by electronic message to participate in the content validity of the TNABV. After acceptance, the TNABV was sent electronically. It is noteworthy that the judges had not had previous access to the test, and along with it, the content validity scale was sent to calculate the Content Validity Index (CVI).

Study 2

The participants were invited, for convenience, to, voluntarily, participate in the research, signing the consent form, which explained the research procedures and objectives. After this stage, the application of the TNABV was performed. The application was carried out collectively and individually, in computer laboratories of the institutions that participated in the study, or in the researchers' notebooks, in places that did not provide computers. Although the form of application occurred in different ways, using desktops and notebooks, collectively or individually, the researchers actively participated in all the applications, reading the instructions automatically given by the instrument and solving doubts before performing the test. The total duration of the application was, approximately, 20 minutes. Data collection occurred during the period from 2018 to 2020.

Data analysis

Study 1

The experts' judgment was performed by the CVI parameter with the seven separate experts for the questionnaire. This method is widely used in the health area and is performed when the survey is done quantitatively (Alexandre & Coluci, 2011). The literature suggests that the CVI measures the agreement of judges regarding the items in relation to the content studied (Tibúrcio et al., 2014). According to Alexandre & Coluci (2011), with the CVI, it is possible to analyze each item individually and, then, the instrument as a whole. The total agreement value can vary from 0 to 1. The parameter adopted for the TNABV content validity was 0.80 minimum agreement between experts, as suggested by other studies (Alexandre & Coluci, 2011). To obtain the CVI by items of the TNABV, the sum of the values marked by the judges who rated the specific item as “3” (partially agree) and “4” (strongly agree) was divided by the maximum possible value of the item. In order to obtain the total CVI, the sum of all CVI of the items calculated separately was performed, divided by the number of items on the scale. Both formulas can be viewed in Figure 2 (Alexandre & Coluci, 2011, Tibúrcio et al., 2014).

Study 2

For the analysis, the statistical analysis was performed on software Factor programming, version 11.04.02 x664bits (Ferrando & Lorenzo-Seva, 2017) and R programming, version 4.0.3 (R Core Team, 2020). To investigate the possibility of factoring the data matrix, the Kaiser-Meyer Olkin Measure (KMO) of sampling adequacy and Bartlett's test was performed. The KMO presented a value of 0.90 (BC 95% C.I=0.90 - 0.91), which indicates excellent values (Damásio, 2012). Bartlett's test showed a value <0.001, indicating that the matrix is favorable. These results indicate that it is possible to do the factoring of the data matrix (Damásio, 2012). To investigate the psychometric properties of the TNABV based on the internal structure, an exploratory factor analysis was performed in order to verify the quality of the items and the model adjustment indexes. The exploratory factor analysis was performed using the following criteria: (a) it was computed a bootstrap sample (Number of BC=500) to normalize the non-parametric distribution of data; (b) the estimation method used was Exploratory Robust Maximum Likelihood (RML), because of the continuous nature of the variables used (Morata-Ramirez & Holgado-Tello, 2013); (c) the correlation method used to among the items was the Pearson correlation, because of the nature of the variables selected (Morata-Ramirez & Holgado-Tello, 2013); (d) a direct oblimin was the rotation method chosen to this analysis (Damásio, 2012); and (e) the number of factors was defined by a parallel analysis (Timmerman & Lorenzo-Seva, 2011). In addition, the construct replicability was measured by Generalized H Index (G-H) which values above .80 suggest a well-defined latent variable of the model (Hancock & Mueller (2000) and the closeness to unidimensionality assessment was analyzed by Unidimensional Congruence (UniCo>.95), Explained Common Variance (ECV>.85) and Mean of Item Residual Absolute Loadings (Mireal<.30) indexes to evaluate if the data of the test suggests a unidimensional model (Ferrando & Lorenzo-Seva, 2018).

Furthermore, to measure the reliability and internal consistency of the items, Cronbach's alpha was performed. Values above .80 suggest adequate internal consistency (Damasio, 2012). The correctness of the object-location was considered as the item of the instrument, indicating the participant's WM binding performance. This study was performed using the standard of Bentler and Chou (1987), who suggest a minimum of five participants for each item.

Figure 2
Content Validity Index Formula

$$\textit{CVI per item} = \frac{\textit{Sum of responses "3" or "4"}}{\textit{Max possible value of the item}}$$

$$\textit{CVI total} = \frac{\textit{Sum of CVI per item}}{\textit{Total of items}}$$

Results

Study 1

For the expert judgment, an analysis of the concordance on the statements of each item of the scale was evaluated. The items "a" to "d" of the scale refer to the adequacy of the test to the proposed construct and to the assessment measures, while item "e" concerns the understanding of images by adults and the elderly (Table 1).

Table 1
Values for the Content Validity Index and Scale Items

Scale	CVI Item	CVI Total
a) the TNABV assesses visuospatial memory	1	
b) the test assesses visuospatial working memory	1	
c) based on the Baddeley and Hitch (1974) Multicomponent Model of Operational Memory and its revision in (2000) the test evaluates the visuospatial sketchpad component	1	.98
d) based on Baddeley's Multicomponent Operating Memory Model (2012) the test evaluates the binding in visuospatial memory	1	
e) the test presents items (figures) that are easily visualized for adults and the elderly	.93	

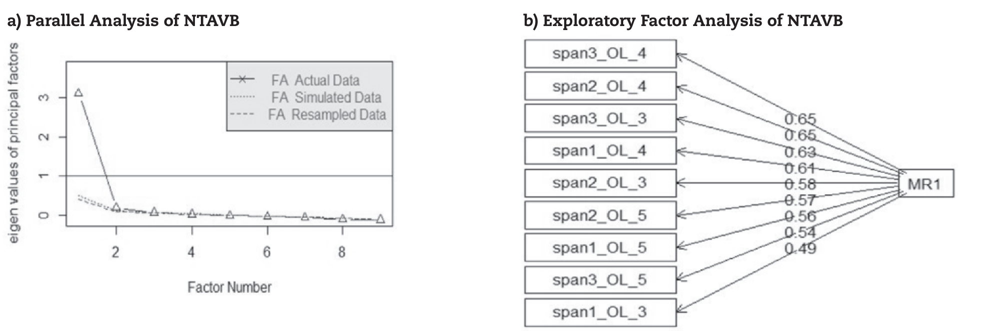
All items from "a" to "d" showed a concordance of 1, that is, 100% – therefore, all experts marked that they "strongly agree" (4) in the adequacy of the items to the proposed model (items "a", "b", "c" and "d"). On the other hand, in the item "e", which assesses whether the stimuli (figures) are visually easy to identify for adults and elderly people, five experts marked that they "strongly agree" (4) and two experts marked that "partially agree" (3), obtaining the CVI value for item "e" of .93. From the results obtained by the item CVI, the total CVI was performed, obtaining a value of .98, which can be seen in Table 3. It is important to note that, even though a space was provided for suggestions and possible adjustments to the TNABV, the experts did not present any written consideration. Therefore, it was not possible to make a qualitative analysis.

Study 2

With the exploratory data analysis, it was possible to identify that the data set has a normal distribution, with a mean of 16.8, standard deviation of 7.44. There was no need to use actions to deal with missings or outliers, as these situations were not observed in the data set. For the investigation of the factor model, a parallel analysis, followed by an exploratory factor analysis were performed, which resulted in a unifactorial model (Figure 3). This one factor suggestion to the test's model is corroborated by the unidimensionality indexes of UniCo, EVC and MIREAL tested (Table 3). The results suggested an explained variance of 41,78% to a unidimensional model. The exploratory factor analysis was performed with the items related to the visuospatial binding process of the test, i.e., the quantity of correct answers of bindings between the object and the location. These items provide the measure of binding of object-location information answered by the participants.

Figure 3

Parallel Analysis and the Tested Model of TNABV



c) Explained Variance Based on Eigenvalues

Variable	Eigenvalue	Proportion of Variance	Cumulative Proportion of Variance
1	3.76088	0.41788	0.41788
2	0.87757	0.09751	
3	0.72510	0.08057	
4	0.69336	0.07704	
5	0.65911	0.07323	
6	0.63306	0.07034	
7	0.57957	0.06440	
8	0.55119	0.06124	
9	0.52017	0.05780	

d) Parallel Analysis Based on Minimum Rank Factor Analysis

Variable	Real-data % of variance	Mean of random % of variance	95 percentile of random % of variance
1	54.2555*	22.4686	28.8063
2	10.9250	19.4182	23.8453
3	8.7176	16.4849	19.4410
4	7.8732	13.7311	16.4835
5	6.0640	11.0123	13.6604
6	5.6892	8.3061	11.3047
7	4.3087	5.6686	9.1804
8	2.1667	2.9102	6.2467

* Advised number of dimensions: 1

According to the results expressed in Table 2, it seems that the factor loadings exhibit a coefficient value above .40, which means an acceptable index. According to Wang and Wang (2019), the value of .40 is considered an acceptable conservative limit of the variable in the creation of the factor, avoiding the problem of the indeterminacy of the relationship between variables and factors. Regarding the item-rest correlation, results show a value above .30, suggesting a medium effect of correlation between the items with binding effect and the overall score of the TNABV (Field, 2018).

Cronbach's alpha (α) was calculated in order to measure the internal consistency of the object-location items. For the nine items that present the binding effect, the coefficient presented a value equal to .82 (CI-95%=.81 to .84). According to Table 2, if any item of the binding effect was dropped, Cronbach's α would not undergo significant changes in its value. This result suggests adequacy of the internal consistency, because it is above the cut-off criteria established to this study (Damasio, 2012).

Table 3 shows the fit indices of the tested model. Regarding RMSEA, which estimates the average difference between the observed covariance and that of the model, their values were interpreted using the criteria of Wang and Wang (2019): 0=perfect fit; <.05=close fit; .05 to .08=fair fit; .08 to .10=mediocre fit; and >.10 =poor fit. For GFI, which corresponds to the observed covariance proportion that is explained by the model's covariance, Hoyle (2012) suggests that GFI values >.95 indicate an adjustment considered acceptable. Regarding the CFI, which compares the fit of the specified model with the null model that assumes zero covariance between the observed variables, Wang and Wang (2019) suggest that CFI values >.90 as the cutoff point. For TLI, which corresponds to a measure that compares the lack of fit of a model with the lack of fit of the null model, Wang and Wang (2019) suggest TLI values >.90 as the cutoff value, as can be seen in Table 3.

Table 2
Psychometric Properties of the TNABV Binding Items

Item	Factor loading	Communality	Item-rest correlation	Cronbach's α if item dropped
S1_3_OL	.49	.24	.43	.82
S2_3_OL	.58	.33	.51	.81
S3_3_OL	.63	.39	.56	.80
S1_4_OL	.61	.36	.54	.80
S2_4_OL	.65	.42	.57	.80
S3_4_OL	.65	.42	.58	.80
S1_5_OL	.56	.31	.51	.81
S2_5_OL	.57	.32	.52	.81
S3_5_OL	.54	.29	.49	.81

Note. S1=Sequence 1; S2=Sequence 2; S3=Sequence 3; OL=Object-location binding. *e.g.*=S1_3_OL: Binding from the first sequence with 3 stimulus of object/location

Table 3
Fit Indices for the Tested Model of the TNABV

Indexes of the tested model	Value	Bootstrap 95% Confidence Intervals
GFI	.996	0.995 - 0.997
CFI	.992	.989 - .993
TLI	.989	.986 - .991
RMSEA	.037	.034 - .038
G-H Index	.829	.812 - .840
UniCo	.991	.989 - .994
ECV	.911	.901 - .927
MIREAL	.158	.119 - .172

Note. GFI=goodness-of-fit index; CFI=comparative fit index; TLI=Tucker-Lewis index; RMSEA=root mean square error of approximation; G - H index=generalized h index to construct replicability; UniCo=unidimensional congruence; ECV=explained common variance; MIREAL=mean of item residual aboslute loadings

Discussion

This study aimed to verify the reliability and the evidence of validity based on content and internal structure of the TNABV, an instrument to evaluate WM visuospatial binding. It was found that the instrument presented adequate results related to its items and the content of the test, which provide a first evidence that the TNABV is understandable and can measure what its propouses, i.e., visuospatial bindings of WM.

According to the concordance criterion adopted to CVI (CVI>.80) in this study of evidence validity based on content (Alexandre & Coluci, 2011), it was possible to observe that the CVI for each item of the scale was in full agreement (1) for items "a" to "d". This suggests that there is a concordance among the experts on the adequacy of the TNABV to the proposed theoretical model. The item "e", which addresses the ability of visual understanding of the figures for adults and the elderly, presented a concordance of .93, indicating a level within the recommended in the literature. Although the CVI result for this item is within the recommended range, it is important to emphasize that the number of experts used for the analysis was seven, which may not be considered a large sample for some authors. Therefore, it is important to analyze the result of this item carefully. A possible measure to solve this question would be the use of a sample with similar characteristics to this population, properly analyzing this information. For the total CVI, the value obtained was

0.98, indicating a degree of concordance above that suggested (Alexandre & Coluci, 2011).

Although no qualitative considerations have been made about the disagreement of item "e", some reasons can be inferred. As mentioned in this study, the TNABV presents items simulating a real situation, the selection of attention and the recognition of the stimulus item (figure) can present emotional, motivational, compensatory strategies, relevant and/or personal experiences (Robertson & Schmitter-Edgecombe, 2016). It is important to highlight that the images presented in the instrument were taken from a study of standardization of figures for the Brazilian population (Pompéia et al., 2001). The development of tests with ecological characteristics is a challenge, due to the possibility of noise, i.e, variables that are not controlled. Some people may experience more difficulty in recognizing certain figures. However, in instruments with ecological characteristics, the performance in the assessed competence may be closer to reality (Robertson & Schmitter-Edgecombe, 2016).

Another hypothesis for the lack of agreement presented in item "e", which corresponds to the ease of understanding of the figures for adults and the elderly, may be due to the gradual accumulation of error resulting from noise in memory. It would be due to the presentation of short sequences of exposures to multiple stimuli, which may indicate the difficulty in recognizing some figures during the test (Ma et al., 2014). As the test progresses, it is possible that the expert has encountered difficulties resulting from prolonged exposure to different complex stimuli, generating less recognition accuracy (Ma et al., 2014).

In the exploratory factor analysis, since the items presented factor loadings above .40, it was not necessary to exclude any item. The item-rest correlation showed a result above .30, indicating a correlation of medium effect between the items and the overall score (Field, 2018). These results indicate how correlated the items are with the factor, assuming that items with correlations below this value should be excluded from the test. The instrument had a Cronbach's α of .82. It is possible to suggest that the internal consistency value of the measure is adequate, being within the acceptable parameter above .80 (Field, 2018). The adjustment indexes of the unifactorial model were considered within the ideal parameters (Wang & Wang, 2019; Ferrando & Lorenzo-Seva, 2018), suggesting that the instrument presents consistent values that support the model.

Some limitations were presented in this study. The participants' only variables were gender and age. Socioeconomic data and education are important and the literature indicates that socioeconomic factors have a positive influence on performance in WM measures (Sbicigo et al., 2013). The CVI scale presented objective assertions, aiming at calculating the index. However, even after providing the scale with the possibility of making suggestions, no recommendations or revisions were made, and a qualitative analysis was not possible to be done.

In summary, the present study evaluated the adequacy of the TNABV with the multicomponent WM model, suggesting an acceptable agreement among experts on the ability to assess the binding effect by the test and the adequacy of the items to a unidimensional model. Which corroborates the theoretical model of object-location information integration of the visuospatial working memory binding (Baddeley, 2012). The TNABV can assist as a way of confirming the effectiveness of interventions in WM with subjects undergoing neuropsychological rehabilitation. In the context of neuropsychological assessment, more than one diagnostic resource to test WM is necessary. A more accurate assessment may contribute to a better intervention increasingly focused on the individual's needs. With the possibility of discovering difficulties in WM as early as possible, it is possible to enable a more accurate and effective rehabilitation to individuals with WM visuospatial binding impairments.

Acknowledgments

We thank to the Clinical Cognitive Neuropsychology Research Group (Neuroclic) and the Universidade Federal da Bahia our best regards for all the support given to us to the development of this study.

Financing

This work was based on an original study that was partially supported by Conselho Nacional de Desenvolvimento Científico e Tecnológico [grant number 445857/2014-5].

Author contributions

We declare that all authors participated in the preparation of the manuscript. Specifically, the authors Yuri Santana, Jonatas Bessa e Neander Abreu participated in the initial writing of the study – conceptualization, investigation, visualization, the authors Yuri Santana, Jonatas Bessa e Neander Abreu participated in the data analysis, and the authors Yuri Santana, Jonatas Bessa, Marian Assolin, Camilla Barretto, Milena Ramos e Neander Abreu participated in the final writing of the work – revision and editing.

Availability of data and materials

All data and syntax generated and analysed during this research will be treated with complete confidentiality due to the requirements of the Ethics Committee for Research in Human Beings. However, the dataset and syntax that support the conclusions of this article are available upon reasonable request to the main author of the study.

Conflict of interests

The authors declare that there are no conflicts of interest.

References

Abreu, J. N. S., Oliveira, A. T., Canário, N. G., Bessa, J. R. C., Santana, Y. E. G., & Duarte, T. (2018). Teste de Arrumação do Armário. Em L. F. Malloy-Diniz, D. Fuentes, P. Mattos & N. Abreu (Eds.), *Avaliação Neuropsicológica.* (pp. 367 - 370). Artmed Editora.

Alexandre, N. M. C. & Coluci, M. Z. O. (2011). Validade de conteúdo nos processos de construção e adaptação de instrumentos de medidas. *Revista de Ciência e Saúde Coletiva, 16*(7), 3061-3068. doi.:10.1590/S1413-81232011000800006

Baddeley, A. D., & Hitch, G. J. (1974). Working memory. *The psychology of learning and motivation: Advances in research and theory, 8*, 47-90. New York: Academic Press. https://doi.org/10.1016/S0079-7421(08)60452-1

Baddeley, A. D. (2012). Working memory: theories, models, and controversies. *Annual Review of Psychology, 63*, 1-29. https://doi.org/10.1146/annurev-psych-120710-100422

Bentler, P. M., & Chou, C. P. (1987). Practical issues in structural modeling. *Sociological Methods & Research, 16*(1), 78-117. https://doi.org/10.1177/0049124187016001004

Damásio, B. F. (2012). Uso da análise fatorial exploratória em psicologia. *Avaliação Psicologica: Interamerican Journal of Psychological Assessment, 11*(2), 213- 228.

Dunning, D. L., Westgate, B., & Adlam, A.-L. R. (2016). A meta-analysis of working memory impairments in survivors of moderate-to-severe traumatic brain injury. *Neuropsychology, 30*(7), 811-819. https://doi.org/10.1037/neu0000285

Ferrando, P. J., & Lorenzo-Seva U. (2018). Assessing the quality and appropriateness of factor solutions and factor score estimates in exploratory item factor analysis. *Educational and Psychological Measurement, 78*, 762-780. https://doi.org/10.1177/0013164417719308

Ferrando, P.J., & Lorenzo-Seva, U. (2017). Program FACTOR at 10: origins, development and future directions. *Psicothema, 29*(2), 236-241. https://doi.org/10.7334/psicothema2016.304

Field, A. (2018). *Discovering Statistics Using IBM SPSS Statistics.* 5th ed. Sage

Goodman, M. S., Kumar, S., Zomorrodi, R., Ghazala, Z., Cheam, A. S. M., Barr, M. S., … Rajji, T. K. (2018). Theta-Gamma Coupling and Working Memory in Alzheimer's Dementia and Mild Cognitive Impairment. *Frontiers in Aging Neuroscience, 10*, 1-10. https://doi.org/10.3389/fnagi.2018.00101

Gold, J. M., Barch, D. M., Feuerstahler, L. M., Carter, C. S., MacDonald III, A. W., Ragland, J. D., ... & Luck, S. J. (2019). Working memory impairment across psychotic disorders. *Schizophrenia Bulletin, 45*(4), 804-812. https://doi.org/10.1093/schbul/sby134

Gramunt, N., Sánchez-Benavides, G., Buschke, H., Lipton, R. B., Masramon, X., Gispert, J. D., … Molinuevo, J. L. (2016). Psychometric Properties of the Memory Binding Test: Test-Retest Reliability and Convergent Validity. *Journal of Alzheimer's Disease, 50*(4), 999-1010. https://doi.org/10.3233/jad-150776

Hancock, G. R., & Mueller, R. O. (2000). Rethinking construct reliability within latent variable systems. In R. Cudek, S. H.C. du Toit & D. F. Sorbom (Eds.), *Structural equation modeling: Present and future* (pp. 195 - 216). Scientific Software.

Hitch, G. J., Allen, R. J., & Baddeley, A. D. (2020). Attention and binding in visual working memory: Two forms of attention and two kinds of buffer storage. *Attention, Perception, & Psychophysics, 82*(1), 280-293. https://doi.org/10.3758/s13414-019-01837-x

Hoyle, R. H. (Ed.). (2012). *Handbook of structural equation modeling.* Guilford press.

Ma, W. J., Husain, M., & Bays, P. M. (2014). Changing concepts of working memory. *Nature Neuroscience, 17*(3), 347–356. https://doi.org/10.1038/nn.3655

Morata-Ramírez, M. D. L. Á., & Holgado-Tello, F. P. (2013). Construct validity of Likert scales through confirmatory factor analysis: A simulation study comparing different methods of estimation based on Pearson and polychoric correlations. *International Journal of Social Science Studies, 1*(1), 54. https://doi.org/10.11114/ijsss.v1i1.27

Parra, M. A., Abrahams, S., Logie, R. H., Mendez, L. G., Lopera, F., & Della Sala, S. (2010). Visual short-term memory binding deficits in familial Alzheimer's disease. *Brain, 133*(9), 2702-2713. https://doi.org/ 0.1093/brain/awq148

Pompéia, S., Miranda, M. C., & Bueno, O. F. A. (2001). A set of 400 pictures standardised for Portuguese: norms for name agreement, familiarity and visual complexity for children and adults. *Arquivos de Neuro-psiquiatria, 59*(2B), 330-337. https://doi.org/10.1590/S0004-282X2001000300004

R Core Team (2020). *R: A language and environment for statistical computing.* R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/

Robertson, K., & Schmitter-Edgecombe, M. (2016). Naturalistic tasks performed in realistic environments: a review with implications for neuropsychological assessment. *The Clinical Neuropsychologist, 31*(1), 16-42. https://doi.org/ 10.1080/13854046.2016.1208847

Sbicigo, J. B., Abaid, J. L. W., Dell'Aglio, D. D., & Salles, J. F. (2013). Nível socioeconômico e funções executivas em crianças/adolescentes: revisão sistemática. *Arquivos Brasileiros de Psicologia, 65*(1), 51-69.

Tibúrcio, M. P., Melo, G. S. M., Balduíno, L. S. C., Costa, I. K. F., Dias, T. Y. A. F, & Torres, G. V (2014). Validação de instrumento para avaliação da habilidade de mensuração da pressão arterial. *Revista Brasileira de Enfermagem, 67*(4), 581-587. https://doi.org/10.1590/0034-7167.2014670413

Timmerman, M. E., & Lorenzo-Seva, U. (2011). Dimensionality Assessment of Ordered Polytomous Items with Parallel Analysis. *Psychological Methods, 16*, 209-220. https://doi.org/10.1037/a0023353

Wang, J., & Wang, X. (2019). *Structural equation modeling: Applications using Mplus.* John Wiley & Sons.

recebido em junho de 2020
aprovado em setembro de 2021

Sobre os autores

Yuri Eduardo Gomes de Santana é Psicólogo (UFBA), mestre em Psicologia do Desenvolvimento (UFBA). Atualmente, é membro do Laboratório de Neuropsicologia Clínica e Cognitiva.

Jonatas Reis Bessa da Conceição é Psicólogo (UFBA), mestre em Psicologia do Desenvolvimento (UFBA). Atualmente, é doutorando em Psicologia (UFBA) e membro e membro do Laboratório de Neuropsicologia Clínica e Cognitiva.

Marian Assolin Abou Abbas é Estudante de Psicologia (UFBA) e membro do Laboratório de Neuropsicologia Clínica e Cognitiva.

Camilla Oliveira dos Santos Barretto é Estudante de Psicologia no Centro Universitário Uninassau e membro do Laboratório de Neuropsicologia Clínica e Cognitiva.

Milena Figueiredo Ramos é Estudante de Psicologia no Centro Universitário Uninassau e membro do Laboratório de Neuropsicologia Clínica e Cognitiva.

Neander Abreu é Doutor em Neurociências e Comportamento (USP). Atualmente, é professor associado no Instituto de Psicologia da Universidade Federal da Bahia e coordenador do Laboratório de Neuropsicologia Clínica e Cognitiva.

Como citar este artigo

Santana, Y. E. G., Bessa, J. R., Abbas, M. A. A., Barretto, C. O. S., Ramos, M. F., & Abreu, N. (2022). Validity evidence for the neuropsychology test for the assessment of visuospatial binding: a working memory test. *Avaliação Psicológica, 21*(2), 227-235. http://dx.doi.org/10.15689/ap.2022.2102.20888.10