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Auditory sequential memory and verbal memory in students with intellectual disability

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Abstract

Introduction. Baddeley's model of working memory establishes the basis for identifying components that intervene in immediate repetition verbal tasks. Based on this model, the overall aim of the present study was to analyze the relationship between auditory sequential memory and verbal memory in students with intellectual disabilities and thereby propose a scale with which to compare each subject's test scores, by mental age.

Method. Quantitative, non-experimental, cross-sectional, descriptive, and correlational study. Incidental non-probabilistic sample including 250 students with intellectual disabilities (123 female and 127 male students), who were assessed using the auditory sequential memory sub-test of the Illinois Test of Psycholinguistic Aptitudes (ITPA) and the two lists of sentences from the Sentence Repetition Test (SentRep) with high semantic and high syntactic load.

Results. Significant, positive relationships were observed between the semantic and morpho-syntactic mediation lists and verbal memory, and also between each of these, the subject's mental age and auditory sequential memory. These results support the construction of two rankings to establish mental age equivalent in repetition of the two sentence types, in verbal memory, and in auditory sequential memory.

Discussion/Conclusions. The tests applied here have been shown to be complementary, and the two rankings we constructed allow a subject's scores to be compared against his/her group. However, a future proposal is to expand the sample and thereby obtain norm referencing that represents the population with intellectual disabilities and supports the formulation of diagnostic hypotheses about the functional level attained by these students in phonological, syntactic and semantic processing.

Key words: Working memory, Sentence repetition, Neuropsychological assessment, Language, Intellectual disability.

Resumen

Introducción. El modelo de Baddeley sobre memoria de trabajo establece la base para identificar los componentes que intervienen en las tareas de repetición inmediata de materiales verbales. Partiendo del mismo, se propone este estudio cuyo objetivo general es analizar la relación entre memoria secuencial auditiva y memoria verbal en alumnado con discapacidad intelectual y, así, proponer una escala que permita comparar, según la edad mental, las puntuaciones de cada sujeto en estas pruebas.

Método. Estudio cuantitativo, no experimental, transversal, descriptivo y correlacional. Muestra no probabilística incidental en la que participaron 250 alumnos con discapacidad intelectual (123 alumnas y 127 alumnos), evaluados mediante el subtest de memoria secuencial auditiva del Test Illinois de Aptitudes Psicolingüísticas (ITPA) y las dos listas de oraciones con alta carga de significado y gramatical del Test Sentence Repetition (SentRep).

Resultados. Se observan relaciones significativas y positivas entre las listas de mediación semántica y morfosintáctica, y la memoria verbal, e igualmente entre cada una de ellas, la edad mental del sujeto y la memoria secuencial auditiva. Resultados que sustentan la construcción de dos baremos para establecer la edad mental equivalente a la repetición de los dos tipos de oraciones, en memoria verbal y en memoria secuencial auditiva.

Discusión/Conclusión. Se ha demostrado la complementariedad de las pruebas aplicadas y que los baremos construidos permiten comparar las puntuaciones obtenidas por un sujeto en relación a su grupo. No obstante, una propuesta futura es extender la muestra y, de este modo, obtener baremos representativos de la población con discapacidad intelectual que apoyen la formulación de hipótesis diagnósticas sobre el nivel funcional alcanzado por este alumnado en el procesamiento fonológico, sintáctico y semántico.

Palabras clave: Memoria de trabajo, repetición de oraciones, evaluación neuropsicológica, lenguaje, discapacidad intelectual.

Introduction

Intellectual disability in childhood and adolescence, and its corresponding educational intervention, have been addressed throughout different periods by the theoretical approaches of the day. An initial model, limited to caregiving, has given way since the second half of the 20th century to a model that seeks to enhance these students' cognitive functions and resources. All conceptualizations of intellectual disability include the presence of significant limitations at the cognitive level, but also limitations in adaptive behavior suited to their surroundings. According to the DSM-V (APA, 2013), intellectual development disorder is defined as deficits in intellectual functioning, such as "reasoning, problem solving, planning, abstract thinking, judgment, academic learning, and learning from experience" (p. 33). Among such deficits that cause difficulties for students to adapt and acquire autonomy and independence, there are deficits relating to communication, which is prior to language, and may therefore interfere with their learning (Guerra & De la Peña, 2017).

Students with intellectual disabilities usually have impairments in verbal communication that, depending on individual characteristics and degree of disability, influence the intensity and type of the language impairment that hinders the organization and expression of information—at the phonological, semantic, morphosyntactic, and pragmatic levels (Peña-Casanova, 2013). Studies have shown that learning in students with intellectual disabilities is facilitated through the use of strategies that combine non-verbal and verbal language, and that attention and memory influence information comprehension and interpretation, which, once it has been related to previous knowledge, brings about meaningful learning (Miolo, Chapman & Sindberg, 2005, Stephenson & Dowrick, 2005). Based on these difficulties, tasks that require repetition of digits, sentences, pseudowords, words and sentences have been used in the assessment of students with intellectual disability. However, few studies have tried to integrate these into a theory, by which to create instruments and procedures for interpreting, assessing and diagnosing the components and processes that intervene in these tasks (Sedó, 2004).

The model most often used to solve interpretation issues is Baddeley's model of working memory, which identifies the constituents involved in immediate oral repetition tasks, how they act and how they relate to each other. Both in its original version (Baddeley, 1986; Baddeley & Hitch, 1974) and in later revisions (Baddeley, 2000, 2007, 2010, 2012; Baddeley

& Hitch, 1994; Baddeley, Hitch & Allen, 2009), this model has received much support from Cognitive Psychology and Neuroscience.

Subsequent research has demonstrated that working memory is closely related to individuals' performance level on numerous cognitive tasks, and to the way they handle everyday tasks (D'Esposito & Postle, 2015; García-Madruga & Fernández, 2008; Pelegrina, Lechuga, Castellanos & Elosúa, 2016). Working memory has also been proven essential in understanding information and in learning transfer, and seems to be a better predictor of academic achievement than IQ, which would support its strong relationship to learning (Alloway & Alloway, 2010; Soprano & Narbona, 2007).

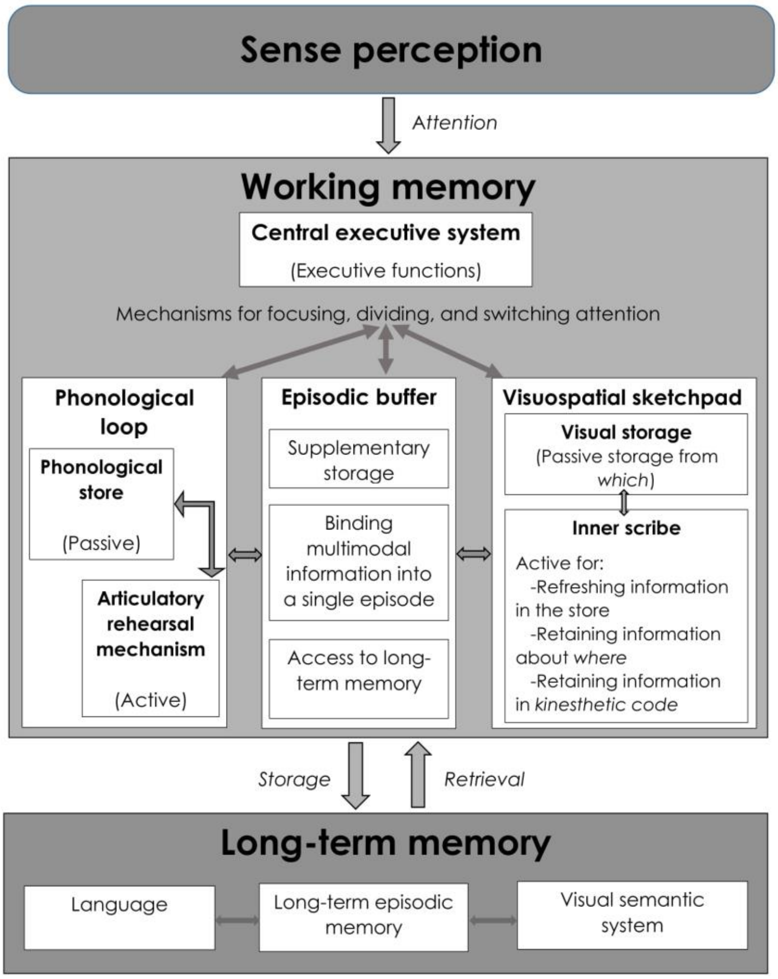

Figure 1. *Multicomponent model of working memory, adapted from Baddeley (2000, 2007, 2012). (Source: prepared by the authors)*

Baddeley's model of working memory is a comprehensive model that proposes a four-component system: the central executive, phonological loop, episodic buffer and visuospatial sketchpad (see Figure 1). This system explains how we record, maintain and temporarily manipulate information when carrying out complex tasks like language comprehension, reading, reasoning, problem solving, and so on (Baddeley & Lieberman, 2017).

The central executive system is an active component that is related to executive functions, primarily involving the prefontal cortex (D'Esposito & Postle, 2015; De Noreña, Blázquez, González & Gil, 2012; Goldman-Rakic, 1998; Ruiz-Vargas, 2010; Tirapu-Ustárroz & Grandi, 2016). Within the model, the central executive supervises and generally oversees the other components, distributing and allocating processing resources by using mechanisms to focus attention, divide attention and switch attention. But this system lacks storage capacity, so it carries out its functions with information temporarily stored in the other systems.

The phonological loop specializes in temporary storage of small quantities of verbal information that has been heard, where it remains available for very short time periods. This process is very important for language acquisition in early childhood (Hamada & Koda, 2011; Verhagen & Leseman, 2016; Weill, 2011) and for reading and writing in school age (Swanson, Zheng & Jerman, 2009). Neuroanatomically, it is closely linked to left hemisphere structures and dorsal pathways that are related to processing speech sounds and sensory-motor integration, especially Wernicke's area, the angular gyrus, the supramarginal gyrus, the premotor cortex, the anterior insula, posterior inferior frontal cortex, and the anterior and posterior sections of the arcuate fasciculus that connects all these areas (Adrover, Marron, Sánchez & Miranda, 2014; Friederici & Gierhan, 2013; Hickok & Poeppel, 2015; Tirapu-Ustárroz & Grandi, 2016). The phonological loop is divided into two components. The first is the phonological store; information heard goes here automatically without exception, and is kept passively for short periods of time, because the memory trace fades quickly. This is similar to short-term auditory sequential memory, representing the primary ability of short-term phonological sequential memory (Baddeley, 2012; Cowan, 2008). The second component is the articulatory rehearsal mechanism (overt or covert), which is a more active process in which stored information is refreshed, preventing its rapid decay by means of a repetitive loop, where the information is also transformed by pronouncing visual information (written words, letters, numbers, images, etc.) with verbal labels (recoding visual into phonological) (Manso & Ballesteros, 2003).

The episodic buffer is a component that has been introduced into more current revisions of the model (Baddeley, 2000, 2007, 2012; Baddeley et al., 2009). This buffer is a limited-capacity, temporary store, and has rather complex organic bases; the hippocampus and the ventromedial prefrontal cortex are integrative elements, and two networks are comprised. The first network specifies the entities' conceptual and motivational value to the individual, through the joint action of the perirhinal cortex, the amygdala, the anterior ventral temporal cortex and the lateral orbitofrontal cortex. The second network creates a mental model of the situation containing spatio-temporal, mentalistic and social markers, through the joint action of the parahippocampal cortex, the retrosplenial cortex, the posterior cingulate, the precuneus, the angular gyrus, the mammillary bodies, the anterior thalamus, and medial prefrontal cortex (Ranganath & Ritchey, 2012; Ritchey, Libby & Ranganath, 2015). Unlike the visuospatial sketchpad and the phonological loop, the episodic buffer is multimodal and multidimensional; it is responsible for integrating the information from the sketchpad and the loop (where specific sense-perception inputs of the current experience are stored and codified) with knowledge stored in long-term memory (semantic-visual knowledge, linguistic knowledge, knowledge from episodic memory, etc.). All this generates a coherent, single representation (an episode) that enables a conscious, subjective sensation of the experience being lived. Some of its main functions are to serve as extra storage, supplementing the phonological loop and the visuospatial sketchpad; and to allow access to the knowledge stored in long-term memory that relates to the task in progress and the sense perception input, facilitating the use of this prior knowledge by all the components of the system and, in addition, binding the diverse multimodal information into one conscious episode, coherent and meaningful.

Finally, the visuospatial sketchpad is specialized in the temporary storage (for brief time periods) of three types of information: visual with meaning, visuospatial, and kinesthetic (Baddeley, 2012; Galvez-Pol, Forster & Calvo-Merino, 2018; Smith & Pendleton, 1990). Neuroanatomically it is related to parietal-temporal-occipital areas, the frontal eye field and the inferior frontal gyrus (Adrover et al., 2014). Within the sketchpad there is a difference between the passive component (cache or visual store) that is responsible for the passive storage of visual information, and the active component (inner scribe) that is responsible for reviewing and refreshing the visual information in the cache, retaining information about locations and retaining information on movement sequences (Logie, 2011).

Baddeley's model argues that there are some factors that can increase the primary amplitude of memory, such as review, or the use of recoding strategies or information organization (chunking). The limited capacity of primary memory can be overcome by grouping several items into higher-order units or chunks (several elements combined into a single unit constitute a chunk). For example, if we have to remember the sequence “p, s, l, k”, four units are involved, but if we have to remember “p, l, a, n”, and we group these letters into the word “plan”, there is only one unit. The same can be said of remembering lists of words, if it is possible to group them into a sentence. This is possible thanks to processes carried out in the episodic buffer, which, as has been pointed out, is interconnected with the other components of working memory (those responsible for sense-perception inputs and control of the activity) and with long-term memory (previous knowledge), placing it at an advantage for integrating and organizing information.

Regarding working memory and verbal material, Baddeley and Lieberman (2017) indicate a superiority effect for immediate recall of sentences, more than lists of unrelated words (superiority effect of sentences). According to these authors, executive and attentional processes are not critical for this effect to appear, because it is linked to automatic semantic and morphosyntactive coding of sentences in the episodic buffer, with support from previous knowledge and abilities. In other words, memory for sentences (whether they have a high semantic load--open, natural sentences--or a high morphosyntactic load --restrictive sentences) benefit from a process whereby short-term storage of the phonological input (in the phonological store) interacts with previous semantic and linguistic knowledge to join groups of elements into larger fragments. The episodic buffer is responsible for integrating the different types of information, mainly relying on automatic coding based on morphosyntactic sequential processes (in the case of restrictive sentences), and on automated semantic coding mechanisms based on meaning (in the case of open, natural sentences).

Phonological impairment has been frequently observed in the language production of students with special needs, particularly of students who present intellectual development disorder. There are deficits in the ability to repeat sequences of symbols or auditory sequential memory, which requires storage and later recall of verbal and auditory information following the same order as the initial presentation (Kirk, McCarthy & Kirk, 2004). Prior studies confirm that the deficit in the phonological component is associated with low psycholinguistic skills, particularly with auditory and verbal sequential memory, hindering the analysis and recall of a word, and consequently, the ability to correctly reproduce it later. As a result, self-regulation and attention skills, developed through specialized mechanisms, are required (Arévalo & León, 2019; Fernández & Gràcia, 2013; Hidalgo, 2014; Muñoz, González & Lucero, 2009).

In the school setting, testing of auditory sequential memory and verbal memory has been used jointly. While they may be complementary, this has not allowed for their integration into a single procedure which is suitable for assessment and diagnosis of intellectual disability. Many difficulties are found in interpreting the data obtained with some of the existing instruments, and from the absence of a general model that allows us to establish which mental functions intervene in the tasks on each test and how they are related to each other.

Objectives

With a view to optimizing assessment, diagnosis and intervention in students with intellectual disability, the aim of the present study was to analyze relationships between auditory sequential memory and verbal memory, taking into account the mental age of students with this type of neurodevelopmental disorder. In doing so, the intent was to establish score-based indices that enable us to make interpretations concerning both types of memories according to the subject's mental age, and thus be able to compare this with the child's own development and with the group of membership, verifying the degree of development that has been attained in each of these memories and detecting strong and weak points in the subject's development.

Method

Participants

The initial participants in this incidental, nonprobabilistic sample were 265 students with intellectual disability who were enrolled in a Special Education school in the Autonomous Region of Madrid, Spain. The data obtained were part of the results from psychopedagogical assessments used for educational purposes, administered to the entire student body.

These students were administered an adapted version of SentRep (starting with the first item in each case), and the test of auditory sequential memory (ASM) from the Illinois Test of Psycholinguistic Aptitudes (ITPA). The latter served as criterion for establishing the mental age of each student in functions typical of the phonological store, given that their intellectual disability precluded working with their chronological age.

After applying the criterion test, cases were selected where a mental age equivalent could be attributed to them based on their raw test scores. The final sample was thus reduced to 250 pupils with intellectual disability, 127 male and 123 female, with chronological ages between 7 and 20 years, and an average IQ of 48 as assessed by the WISC-IV (Wechsler, 2005).

Instruments

Illinois Test of Psycholinguistic Aptitudes (ITPA) (Kirk et al., 2011), in its Spanish adaptation by Ballesteros and Cordero (2011). Made up of 12 subtests, the ITPA evaluates psycholinguistic skills at the representational and automatic levels in children between the ages of 3 and 10. The main objective of this test is to detect the existence of impairment or difficulty in the communication process (deficiencies in perception, interpretation or transmission), which may be at the root of most scholastic learning problems. Complementarily, it also seeks to identify any skills or positive conditions that might help support a remedial program. In this study we used the auditory sequential memory (ASM) subtest, which is one of the tests most often used in assessing students with intellectual disability. It contains 26 series that assess immediate recall of nonmeaningful verbal input, through repetition of series of two to eight digits, presented at a speed of two per second. The series are presented one at a time, so that the subject may repeat it and say what he or she remembers; the test is discontinued when the subject fails three consecutive series. Internal consistency, for each scale of the instrument and according to age, presented Cronbach values between .74-.90; values for the auditory sequential memory test were between .79-.87.

Sentence Repetition Test (SentRep) by Sedó (1990, 2004). The test requires repetition of two lists of sentences of identical length, differing only in their use of simple or complex syntax. Sentence length in both lists increases progressively, up to 30 syllables.

Length: The L list uses only two-syllable words, making it possible to perfectly control the length of the sentences, which increase by adding one two-syllable word after two sentences of the same length (2, 2, 4, 4, 6, 6, 8, 8 syllables, etc.).

Complexity: In the C list, the length increases by only one syllable at a time, but the sentence structure is markedly different, introducing a great number of morphosyntactic markers (gender, number, verb tenses, double verbs, questions, compound forms, etc.). Examples of L sentences and C sentences (in italics), having the same length in syllables, are shown below; English translations follow in parentheses.

2: Adiós (Good-bye)
2: *Se fue (He left)*
4: Buenas noches (Good night)
4: *No me lo dio (He didn't give it to me)*
6: Hace mucho calor (It's very hot)
6: *¿Qué más quieren hacer? (What else do they want to do?)*

Although the original test indicates starting points according to age, for this study each list was applied beginning with its first item, given that study participants presented intellectual disability. The test allows subjects to be compared not only with external norms, but also with themselves, in their reactions to the L list and the C list.

The Sentence Repetition test is a test for clinical use that can complement the ITPA test in auditory sequential memory, because it introduces a comparison between the immediate repetition of two lists of sentences, of increasing length in number of syllables, differing only in their use of simple or complex syntax. Using the SentRep, the following can be established: 1) a developmental index of immediate verbal memory when this is mediated fundamentally by simple verbal comprehension (list L); 2) an index of the development of immediate verbal memory based on the linguistic comprehension of the complexity of the sentence and on the level of the subject's expressive grammar—given that we can only accurately repeat sentences that we know how to produce spontaneously (list C); and (3) an "ipsative" score (C - L) that, by comparing the subject to himself/herself, establishes the relative development that has been attained in these two memories with respect to each other, thereby detecting developmental strengths and weaknesses.

Procedure

A quantitative, non-experimental, cross-sectional, descriptive and correlational study was designed. Data were collected in the different assessments that are part of the school's psychoeducational protocol; testing took place in regular class hours. In all cases, the students' parents or legal guardians previously signed their informed consent, in which they were also guaranteed strict confidentiality, anonymity, and careful protection of the data collected by the research team. The study was not reviewed by any commision, given that prospective research designs do not require approval from an ethics committee.

Data analyses

We carried out exploratory factor analysis using the principal components method with varimax rotation in order to validate the ranking scale formed by the scores obtained on each test. To check whether the data were factorable, we examined the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy, which suggests the presence of a latent factor when its value is close to 1. It was confirmed using the Bartlett sphericity test; when the significance level of this statistic is greater than .05, it does not make sense to carry out a factor analysis of the instrument. In addition, we studied reliability by analyzing internal consistency with Cronbach's alpha coefficient, which is based on the average inter-element correlation, assuming that questionnaire items are strongly correlated. Coefficient values range between 0 and 1, and are considered acceptable if equal to or above .70.

Second, we calculated correlations between the scores on the study instruments and the subject's mental age equivalent, using Pearson's correlation coefficient. Based on the relationships found, two tables were drawn up to establish the equivalence in each of the components that intervene in sentence repetition, the mental age equivalents of the raw scores attained, as well as the ipsative scores corresponding to each mental age. Given that chronological age of students with intellectual disability cannot be used in norm referencing for this population, we decided to use mental age equivalent attained on the auditory sequential memory test of the ITPA (Kirk et al., 2004), given its relationship to primary amplitude of the phonological store—the first of the capacities to be developed (Catani & Bambini, 2014). In this way, new scores were created that make it possible to complement the assessment possibilities of the SentRep, combining them with the significance and potentialities of the auditory sequential memory test of the ITPA, and so compare the scores on these scales according to the subject's mental age.

The database design and all the statistical analyses were performed using the Statistical Package for the Social Sciences (SPSS), version 24.0 for Windows.

Results

Prior to the exploratory factor analysis, we reviewed the sample adequacy measures, a KMO coefficient of .737 and Bartlett's sphericity test ($\chi 2 = 3648.771$, $p < .001$), results that indicated it was appropriate to proceed. A principal components exploratory factor analysis (with varimax rotation) of the scale considered in this study showed an initial single-factor solution that explains 86.11% of the total variance of the construct. Regarding factor loadings, they all fall between .902 and .964, values considered to be strong (Kline, 2014). Table 1 shows the descriptive statistics and the factor loadings of the five measures used in this study. Moreover, the global internal consistency of the constructed scale, calculated with a Cronbach alpha of .889, indicated high reliability.

Table 1. Descriptive statistics and factor loadings of the study tests.

	M	***SD***	**Min-Max**	**Asymmetry**	**Kurtosis**	**Factor loading**
MA	6.07	1.89	3-10	.35	-.82	.920
ASM	7.88	3.42	1-16	.32	-.59	.920
L List	15.24	4.74	0-28	.02	.79	.902
C List	12.32	6.00	0-23	.15	-1.21	.932
VM	27.56	10.21	0-51	.08	-.57	.964

MA: mental age; ASM: auditory sequential memory; L List: semantic mediation with high semantic load; C List: morphosyntactic mediation with high syntactic load; VM: verbal memory (L+C)

In addition, we carried out correlational analysis, with results presented in Table 2. Significant, positive relationships were observed between the semantic and morphosyntactic mediation lists and verbal memory, also between each of these, the subject's mental age and auditory sequential memory. These results support the possibility that these scores may be used to establish a ranking in which equivalent age is associated with raw scores obtained on each list and in verbal memory, and thus be able to compare subjects to themselves and to the group they belong to.

Table 2. *Correlations between mental age, auditory sequential memory, semantic mediation, morphosyntactic mediation and verbal memory*

	MA	**ASM**	**L List**	**C List**	**VM**
MA	1				
ASM	.998**	1			
L List	.715**	.719**	1		
C List	.773**	.770**	.813**	1	
VM	.784**	.785**	.938**	.963**	1

MA: mental age; ASM: auditory sequential memory; L List: semantic mediation with high semantic load; C List: morphosyntactic mediation with high syntactic load; VM: verbal memory (L+C)
** $p < .01$

Groups were configured based on the mental age equivalent assigned to each participant in auditory sequential memory. Each group was then associated with its corresponding raw scores (means) for each sentence list (L-semantic and C-morphosyntactic) and for verbal memory. The results appear in Table 3, and enable us to calculate the a pupil's equivalent age in short-term semantically mediated verbal memory, short-term morphosyntactically mediated verbal memory, and in total verbal memory, based on the raw scores obtained on the two sentence lists (L and C) for verbal memory. These equivalencies help us draw conclusions about the development of short-term memory that is linked to automatic semantic-verbal abilities, to automatic morphosyntactic aptitudes, and to automatic verbal abilities in general.

Table 3. *Means and standard deviations for each mental age group*

Mental Age (years-months)	**N**	**ASM**	**L List** Syllables *M(SD)*	**C List** Syllables *M(SD)*	**VM** Syllables *M(SD)*
3-6	31	3	8.7(3.8)	4.9(2.6)	13.8(5.7)
4-2	31	4.5	11.6(2)	6.8(1.7)	18.5(2.9)
4-9	31	5.7	14.2(2.4)	9.5(3.4)	23.7(4.8)
5-7	32	7.1	14.3(3.4)	10.3(5)	24.7(7.8)
6-4	32	8.3	16.3(2.9)	13.2(4.1)	29.5(6.1)
7-0	31	9.5	17.2(2.8)	16.2(3.7)	33.3(5.8)
7-10	31	11	19.1(3.7)	18.1(3.1)	37.2(6.1)
9-6	31	14	20.5(3.5)	19.5(2.7)	40(5.6)

ASM: auditory sequential memory; L List: semantic mediation with high semantic load; C List: morphosyntactic mediation with high syntactic load; VM: verbal memory (L+C)

Likewise, as seen in Table 4, ipsative scores are calculated from the raw scores and are indexed to the students' mental age equivalent in verbal memory and auditory sequential memory. These indicate, respectively, whether there are statistically significant differences between recall of the two sentence lists or between verbal memory and auditory sequential memory (as long as the difference is greater than one standard deviation). This makes it possible to analyze the development of these components of immediate recall of verbal material, observing its homogeneity or heterogeneity. Thus, to compare verbal memory and auditory sequential memory, we take the age group closest to the age attained in auditory sequential memory, and for the C-L comparison, we take the age group closest to age attained in verbal memory. In both cases, if age falls at an intermediate point between two groups, the older age should be selected, and if it falls outside the extremes, the first or last group should be used.

Table 4. *Ipsative scores according to mental age groups*

Mental Age (years-months)	**N**	**Ipsative Score** *M*(*SD*)	**(C-L Diff.)** Interval	**Ipsative Score** *M*(*SD*)	**(VM-ASM Diff.)** Interval
3-6	31	-3, (3.2)	· -0.5: ≥ 0 · -6.9: ≤ -7	10.8(5,7)	· 16.5: ≥ 17 · 5.1: ≤ 5
4-2	31	-4.8(2,3)	· -2.5: ≥ -2 · -7.1: ≤ -8	13.9(3,1)	· 17: ≥ 18 · 10,8: ≤ 10
4-9	31	-4.7(3,9)	· -1.3: ≥ -1 · -8.3: ≤ -9	18.0(4,9)	· 23,4: ≥ 24 · 13.2: ≤ 13
5-7	32	-4.0(3.3)	· -0.7: ≥ 0 · -7.3: ≤ -8	17.6(8,1)	· 25.7: ≥ 26 · 9.5: ≤ 9
6-4	32	-3.1(3,7)	· 0.6: ≥ 1 · -6.8: ≤ -7	21.2(6,4)	· 27.6: ≥ 28 · 14.8: ≤ 14
7-0	31	-1.0(3,2)	· 2.2: ≥ 3 · -4.2: ≤ -5	23.8(6,1)	· 29.9: ≥ 30 · 17.7: ≤ 17
7-10	31	-1.0(3,1)	· 2.1: ≥ 3 · -4.1: ≤ -5	26.2(6,0)	· 32.2: ≥ 33 · 20.2: ≤ 20
9-6	31	-1.0(2,8)	· 1.8: ≥ 2 · -3.8: ≤ -4	26.0(5.5)	· 31.5: ≥ 32 · 20.5: ≤ 20

Note: Interval that includes scores below and above one standard deviation; C List: morphosyntactic mediation with high syntactic load; L List: semantic mediation with high semantic load; ASM: auditory sequential memory; VM: verbal memory (L+C)

Discussion and Conclusions

The general purpose of this study was to analyze the relationship between auditory sequential memory and verbal memory, as well as the relationship between these variables and the mental age of students with intellectual disability. The relationships found were intended to support the construction of two ranked scales representing the study participants, showing the corresponding scores of each mental-age group, and their scores in auditory sequential memory, in the SentRep sentence lists (L-semantics and C-morphosyntactics) and in verbal memory.

First, an exploratory factor analysis was carried out to evaluate the scale constructed in this study; a single factor explained 86.11 % of the total variance, with factor loadings over .90. Moreover, high internal consistency was confirmed, serving as an indicator of global homogeneity and adequate interdependence of the tests used in the assessment.

On the other hand, correlational analysis confirmed significant, direct relationships between all the variables, allowing us to affirm that the older the mental age, the higher the scores in auditory sequential memory, in both SentRep sentence lists and in verbal memory. This justifies an assertion that each of the lists relates to specific abilities that can be evaluated and compared (each list explains 67% of the variation in the other), and that mental age, calculated from the auditory sequential memory test (considered a criterion test in this study), can be used for the elaboration of ranking scales. All of this is in line with previous studies indicating that ITPA's test of auditory sequential memory reflects the primary ability of short-term phonological sequential memory of the phonological store (Baddeley, 2012; Cowan, 2008; Hidalgo, 2014). List C includes sentences that match what Baddeley et al. (2009) call restrictive sentences, where automatic, short-term morphosyntactic sentence coding mechanisms are applied. Similarly, List L of SentRep includes sentences that match what they call open, natural sentences; these would have to do with the automatic, short-term semantic coding mechanisms of sentences. Consequently, the results of this study justify the need to solve problems related to the use of SentRep in the population with intellectual disability, at the same time endorsing the need to have specific ranking scales for persons with this neurodevelopmental disorder in the Spanish population.

Once the relationships were analyzed and their significance confirmed, several groups were formed according to mental age as determined by scores on the criterion text of auditory sequential memory. For each age group, score equivalencies on the two SentRep lists and on verbal memory were also established, from which we could ascertain the level of development of short-term memory associated with automatic verbal abilities in general, and with semantic and morphosyntactic abilities taken separately. The results obtained on these ranked scales show a tendency in all age groups for a lesser quantity of morphosyntactically-mediated material (List C) to be recalled than semantically-mediated material (List L). Results are in line with Baddeley's model (Baddeley et al., 2009), which affirms that the type of unit formed in episodic memory may be an important factor in its extension and persistence in short-term memory, and whether it passes to long-term memory. The functioning of restrictive sentences in short-term memory is more similar to that of unrelated word lists than to that of open, natural sentences. Restrictive sentences make especial use of automatic morphosyntactic coding, which, while it strengthens the sequential grouping of words, does not enhance persistence over time. However, groupings in the case of open natural sentences are formed using automatic semantic coding mechanisms, which facilitate the passage of information to long-term episodic memory (since semantic fragments have greater meaning and relevance to the individual, and are therefore grouped into larger units and are maintained for a longer time). Lists of unrelated words, however, are unaffected by syntactic coding, semantic coding, or long-term episodic memory. For this reason they are more easily overwritten; the primary amplitud of short-term memory is very limited, and the store must be emptied in order for new inputs to be processed (something similar occurs with the C list sentences with respect to morphosyntactic processing).

On the other hand, although Sedó (2004) claims that in subjects with intellectual disability, both semantic and syntactic resources are significantly reduced, and despite an impression from the overall results that this reduction is always similar in regard to both aptitudes, the study of individual cases shows that there is great heterogeneity, and this is where it makes sense to use the procedure presented in this study.

We also calculated ipsative scores, which, according to the subject's mental age, can indicate significant differences between recall of the sentences presented and auditory sequential and verbal memory. From these differences it may be possible to analyze the homogeneity of development of immediate recall of verbal components of language. The principal utility of the assessment and comparison procedure proposed here is in clinical practice. First, there is the possibility of assessing and establishing a differential diagnosis regarding memory and language difficulties observed in students with intellectual disability, which would help in making decisions about special education and rehabilitation. A new perspective is offered, in that it targets students with intellectual disabilities, although this had already been initiated by Gathercole and Alloway (2008), whose instrument for measuring working memory is able to identify school-age children who are at risk and provide methods to help them (Baddeley, 2012).

There is therefore justification for the complementary nature of the tests applied in this study. From the neuro-anatomical-functional view point, the test of auditory sequential memory would indicate the status of the structures and dorsal pathways of the left hemisphere that relate to processing speech sounds and their sensory-motor integration; List C would indicate the status of the structures and left dorsal pathways of syntactic processing, which are necessary to establish relationships between the components of complex sentences (especially the status of the posterior superior temporal cortex, Broca's pars opercularis and their connection through the long section of the arcuate fasciculus); and list L would indicate the status of the structures and dorsal pathways that process the thematic roles of the sentence constituents (especially the status of the posterior superior temporal cortex, the angular gyrus and its connection through the posterior section of the arcuate fasciculus). These three automatic processes are complementary and necessary for establishing the literal meaning of sentences, essential information for finding the meaning of linguistic messages at higher levels of episodic memory and verbal comprehension (Catani & Bambini, 2014; Hickok & Poeppel, 2015). Similarly, in applied activity, we must also keep in mind that working memory is closely related to learning and to higher mental functions in students with intellectual disability (Hartman, Houwen, Scherder & Visscher, 2010; Schuchardt, Gebhardt & Mäehler, 2016), just as it is in students with typical development (González, Fernández & Duarte, 2016).

There are several study limitations that should be addressed in later research studies. First, there are few assessment instruments for students with intellectual disability; in the use of SentRep, specifically, the problem lies in a lack of standards obtained with a Spanish population, along with the difficulties of norm-referencing that are involved in working with students with intellectual disability. Second, another important limitation has to do with the sample: selection of the study population was nonprobabilistic, and its size and heterogeneity may distort the data in some cases. To produce scales that rank test achievement using a non-representative sample of the population with intellectual disabilities is not the most appropriate; hence, with the results obtained in this study, a priori it is only possible to compare a subject's score in relation to their membership group. It would therefore be advisable to re-elaborate the ranking scales with a considerably larger number of participants and, in addition, expand it to a normal population, since it would be desirable to have adequate ranking scales for this population as well.

Future research could study the usefulness of the procedure presented here for diagnosis, exploration, investigation, intervention and verification of the effects of specific training programs, both in individual cases and in the general characteristics of intellectual disability. Furthermore, the practical implications of this type of research should be taken into account and intervention programs based on the information provided by these assessment procedures should be developed. This can help to confirm whether working memory in students with intellectual disabilities is a better predictor of learning and academic achievement than IQ, just as it is in the data collected from samples of students with typical development (Alloway & Alloway, 2010).

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