Psicothema 2012. Vol. 24, nº 2, pp. 183-187
www.psicothema.com

ISSN 0214 - 9915 CODEN PSOTEG

Developmental pattern of digit span in Spanish population

María Victoria Sebastián and Laura Hernández-Gil
Universidad Complutense de Madrid

This study examined in a Spanish population the developmental pattern of digit span, as an index of one of the components of Baddeley's working memory—the phonological loop. A verbal digit span was administered to 570 participants ranging from 5 to 17 years old. The results indicated that the digit memory span increases until age 17 as opposed to Anglo-Saxon data—where it is established that this span reaches a peak by age 15. Additionally, these results were compared to the performance in the same task of healthy elderly, Alzheimer disease patients, and Frontotemporal dementia patients, examined in a previous study. The analysis shows that the phonological loop is affected by age and not so much by dementias.

Patrón de desarrollo de la amplitud de dígitos en población española. Este estudio examinó el patrón de desarrollo de la amplitud de dígitos, en una población española, como índice de uno de los componentes del modelo de memoria operativa de Baddeley —el lazo fonológico—. Se administró una tarea verbal de amplitud de dígitos a 570 participantes entre 5 y 17 años. Los resultados indicaron que la amplitud de dígitos se incrementa hasta los 17 años, a diferencia de lo que muestran datos anglosajones donde la amplitud máxima se alcanza a los 15 años. Además, estos resultados fueron comparados con el rendimiento en la misma tarea de ancianos sanos, pacientes Alzheimer y pacientes con demencia frontotemporal, que fue examinado en un estudio anterior. Los datos mostraron que el lazo fonológico estaba afectado por la edad y no tanto por las demencias.

The attempt to determine how one is successful in everyday activities, such as correctly remembering a telephone number, may clarify how human memory temporarily stores information. In this sense, short-term memory development during lifespan, as well as its deterioration in neurodegenerative illnesses such as frontal variant of frontotemporal dementia (fvFTD), or Alzheimer's disease (AD) can contribute to reach an integrated perspective of the structure and processes that take place while performing diverse everyday activities.

Short-term memory was first considered as opposed to long-term memory, and it was characterised as a passive store which presented a limited capacity to retain information for a brief period of time (Atkinson & Shiffrin, 1968). Later on, and in contrast to previous conceptions, Baddeley and Hitch (1974) developed a multi-component model, named the working memory model, which emphasizes the active process of the short-term memory (see the recent book by Baddeley, Eysenck, & Anderson, 2009). Broadly, this model comprises four components: the *phonological loop*, which is responsible for the temporary storage of speech-based information; the *visuospatial sketchpad*, responsible for visual-spatial information; the *episodic buffer*, which is a component introduced by Baddeley (2000) in this decade and is characterised by its capacity to integrate information from a variety of sources into episodes and by the limited capacity of its temporary storage system; and finally, the *central executive*, a component of attention that controls and coordinates the activity of the three other components, and of the available processing resources.

Baddeley's working model has been of great value to characterise the temporary memory in children, adult, aged and demented patients. It would be interesting to observe not only at what point the functions that characterise working memory appear, but also its developmental pattern and the differences that are found in the progression of its components throughout childhood and adolescence. Moreover, it might be relevant to observe the changes that can occur during aging or neurodegenerative diseases. Following this line of investigation, the current study intends to analyse the developmental pattern of the phonological loop.

As mentioned, this auxiliary system is responsible for the temporary storage of speech-based information and is, in turn, divided into two subcomponents: the *phonological store*, where small amounts of verbal information are passively retained; and the *subvocal rehearsal*, which is an active process that facilitates the execution of other strategies (e.g., chunking or recoding), resulting in the retention of items for a longer period of time.

To evaluate the phonological loop, simple verbal span tasks (e.g., digit span task) are commonly used, as they require the participant to retain auditorily-presented information in a correct serial order. The digit sequence recall task depends on the phonological loop because the verbal short-term memory store and the subvocal rehearsal are both required to remember what the items are, on the one hand, and the correct order in which they were presented, on the other.

In general terms, performance of these tasks improves from age 6 up to adolescence (i.e., Diamond, 2006). In relation to this,

Fecha recepción: 19-7-11 • Fecha aceptación: 16-11-11
Correspondencia: María Victoria Sebastián
Facultad de Psicología
Universidad Complutense de Madrid
28223 Madrid (Spain)
e-mail: mvsebastian@psi.ucm.es

it has been noted that the phonological loop is present at very early ages: 3-4-year-old children are already capable of retaining information in their phonological store (Hitch & Halliday, 1983; Hulme & Tordoff, 1989). However, children cannot perform subvocal rehearsal until ages 7 or 8; therefore, until this time, the information stored in the phonological loop rapidly decays (Gathercole, 2008). Nevertheless, both storage capacity and speed of subvocal rehearsal experience an overall increase with age. According to Hitch (2006), this development is associated with the child's increasingly faster subvocal articulation, while the decaying rate of the phonological store remains constant with age.

Anglo-Saxon data show that the digit span increases with age until age 15, when it reaches adult levels (Gathercole & Alloway, 2008). It would be interesting to check whether this conclusion can also be derived for the Spanish population, as language differences may affect the generalization of the results: word length is a widely studied effect (Baddeley, Thomson, & Buchanan, 1975; Hulme & Tordoff, 1989) that affects the verbal span both in children (since age 4) and in adults (Hitch, 2006).

As mentioned, processing speed is another factor that develops and increases throughout childhood and adolescence (Fry & Hale, 1996). Relationships between processing speed and memory span have been established (Case, Kurland, & Goldberg, 1982; Hitch, Towse, & Hutton, 2001), as well as between processing speed and executive functions (Fry & Hale, 1996), until the possibility arose that a higher processing speed allows for a larger storage capacity, which would sharpen the phonological loop or visual-spatial store, and as a result, would improve the performance of the working memory. Albeit, Hitch et al., (2001) found that, by controlling processing speed in tasks, the age differences in working memory did not disappear. It seems that the improvement in processing speed during childhood is a general factor that contributes to the development of the working memory, but it is not sufficient by itself.

In summary, performance in tasks that involve working memory processes improve during childhood and, according to several studies, the following overall sequence can be established: the phonological loop and the ability of inhibition in its simplest form is present from early childhood, which would be consistent with the study of Davidson, Amso, Anderson, and Diamond (2006) in which no age group (including children below age 4) had trouble in keeping in mind two different rules that had to be applied in a task; from 4 to 8 years of age, children's memory span increases, a factor that probably facilitates more complex strategies. This sequence coincides with the development of different executive functions which begin to develop around age 5 in their simplest forms, improve substantially until age 11, and continue their development for almost two decades (Diamond, 2006).

On account of all this, the current study investigates the development of the phonological loop in children between ages 5 and 17, by evaluating the verbal digit span**.** In particular, this study examines, firstly, whether the phonological loop capacity, in terms of digit span, increases with age and reaches an asymptotic value at about 15, as has been concluded from the Anglo-Saxon data previously mentioned (Gathercole & Alloway, 2008). Secondly, the results of this study are compared to those obtained in a previous one carried out by Sebastian and Hernández-Gil (2010) that examined the phonological loop by using the same task in adults, aged people, fvFTD and AD patients in order to observe the course and the developmental changes of this function throughout the lifespan, as well as the deterioration in dementias, such as fvFTD and AD.

Method

Participants

A total of five hundred and seventy voluntary participants carried out the experiment. They were selected from public and private Preschools, Primary schools and Secondary schools of the Community of Madrid. All participants had been born in Spain and were selected according to the grade they were in (i.e the thirteen courses of the Spanish education system), in order to control the education and cognitive levels from Preschool (5 years old) to the last year of Secondary school. None of the participants had repeated any year. Also, participants did not present hearing impairments, or difficulties in reading or writing or any other cognitive alterations. The characteristics of participants can be seen in Table 1.

Material

The digit span material consisted of random sequences of digits read aloud by the experimenters at a rate of one per second. An item was added gradually to increase the sequence of the digits.

Procedure

The task was carried out during the participant's breaks. It started with three sequences of three digits. Participants were asked to listen carefully to them and to recall them in the same order as they were presented. An additional digit progressively increased the length of the sequence. An example was given in order to check that they had understood the instructions. Digit span was taken as

Table 1
Spanish Education System in years, number of participants, gender (M / F), means of years and means of months, by course (standard deviations in parenthesis)

Course	Number	Gender: Male (M) / Female (F)	Mean of years	Mean of months
Preschool	46	23 / 23	5.1 (.32)	7 (3.5)
Primary School, 1º	45	22 / 23	6.3 (.53)	7.1 (3.7)
Primary School, 2º	42	15 / 27	7.3 (.71)	6.6 (3.4)
Primary School, 3º	40	25 / 15	8.4 (.68)	6.3 (3.7)
Primary School, 4º	40	19 / 21	9 (1.2)	6.3 (3.4)
Primary School, 5º	40	20 / 20	10.3 (1.1)	5 (3.3)
Primary School, 6º	40	22 / 18	11 (1.3)	5.2 (3.4)
Secondary School, 1º	44	20 / 24	12.1 (1.1)	7.4 (3.1)
Secondary School, 2º	41	20 / 21	13.2 (.97)	6.4 (3.1)
Secondary School, 3º	43	16 / 27	14.1 (1.1)	5.7 (3.4)
Secondary School, 4º	45	26 / 19	15.1 (1.5)	6.1 (3.3)
Secondary School, 5º	51	23 / 28	16.1 (1.0)	6.2 (3.8)
Secondary School, 6º	53	21 / 32	17.1 (.66)	7.3 (2.8)
Total	570	272 / 298		

the maximum length at which participants could recall at least two out of three series with no errors. The task was administered individually to all participants.

Data analysis

The results were analysed in two different ways: by course (i.e. thirteen school years) and by developmental periods (i.e. five different age groups: 5 years, 6-8 years, 9-11 years, 12-14 years, and 15-17 years). A trend analysis was performed in order to check whether the digit span increases by course or by the developmental period, and whether such increase is linear, quadratic or cubic. Due to the fact that the number of samples was uneven among the courses as well as among the developmental periods, and because of the unequal variance in the digit span, the Games-Howell Pairwise Comparison Test was computed.

Results

The overall means in the digit span by courses and by developmental periods can be seen in Table 2. The trend analysis by courses shows that both linear, F (1, 557)= 426.91, MSE= 245.85, p<.0001, and quadratic, F(1, 557)= 22.94, MSE= 13.21, p<.0001) contrasts were significant, but not the cubic contrast, F(1, 557)= .752, MSE= .43.

As can be seen in Table 2, digit span clearly increased with age. Post-hoc comparisons (Games-Howell) showed that very young children (5 years, Preschool, M= 3.76, SD= .52) had a very low digit span and differed significantly from all the age groups. However, from 6 to 8 years old (the first courses of Primary school) a similar digit span was found (6 years, M= 4.16, SD= .56; 7 years, M= 4.26, SD= .54; 8 years, M= 4.63, SD= .54), although it was lower than other age groups. The increase in one digit (from 4 to 5 digits) started at 9 years old, and it rose smoothly until 11 years of age (9 years, M= 5.00, SD= .68; 10 years, M= 5.13, SD= .94; 11 years, M= 5.28, SD= .78), and all these youngsters differed from the older groups. Adolescents from 12 to 14 had a similar digit span (12 years, M= 5.30, SD= .88; 13 years, M= 5.89, SD= .84; 14 years, M= 5.51, SD= .83), but they differed from the older groups. And finally, it was found that the digit span was similar between ages 15 and 17 years old (15 years, M= 5.82, SD= .81; 16 years, M= 5.75, SD= .87; 17 years, M= 5.91, SD= .86).

A trend analysis was also performed in order to check whether digit span increases linearly, quadratically or cubically, by developmental period. The analysis shows that both linear, F(1, 565)= 415.00, MSE= 242.35, p<.0001, and quadratic contrasts, F(1, 565)= 8.40, MSE= 4.90, p<.004, were significant, but not the cubic contrast, F(1, 565)= .61, MSE= .36. Post-hoc comparisons (Games-Howell) confirmed the developmental trend (see Table 2) in increasing digit span towards adulthood (5 years, M= 3.76; SD= .52; 6-8 years, M= 4.34; SD= .58; 9-11 years, M= 5.13; SD= .81; 12-14 years, M= 5.46; SD= .85; 15-17, M= 5.83; SD= .84).

When comparing our data on digit span (Table 2) to the Wechsler Intelligence Scale for Children IV (WISC-IV; Wechsler, 2003) in a broad Spanish population, some differences are observed. The results, in general, are similar, in the sense that digit span increases with age, but our data showed a lower digit span than that of the WISC-IV in all age groups.

The results of this study were compared to those obtained in a study carried out by Sebastian and Hernandez-Gil (2010) in which digit span was assessed in 25 healthy older people as a control group (C), in 25 AD patients, and in 9 fvFTD patients. All participants carried out the same digit span task as in this study. The characteristics of the three groups and their digit span scores can be seen in Table 3.

The performance of the elderly group (Table 3) was compared to the youngest groups of the present study (5 and 6 years), showing that the elderly (M= 4.44, SD= 0.76) had a higher digit span than 5-year-olds [t (38.36)= -4.67, two-tail, p= .0001], and 6-year-olds [t (40.74)= -2.20, two-tail, p= .03]; in contrast, the digit span of the elderly did not differ significantly from other year groups (p>.05).

Comparing the digit span of both kinds of demented patients (Table 3) to the youngest groups, a different pattern of results was found. AD patients' digit span (M= 4.20, SD= 0.65) was also higher than that of the 5-year-olds [t (41.45)= - 2.92, two-tail, p= .006], but it did not differ significantly from other year groups (p>.05).

Table 2
Means of digit Span in WISC IV and means of digit Span in our study, by courses; means of digit Span in our study grouped by developmental period (standard deviations in parenthesis)

Course (age)	Direct digit Span in WISC IV	Direct digit Span in our study	Digit Span in our study by developmental periods
Preschool (5 years)		3.76 (.52)	3.76 (.52)
Primary School (6 years)	4.30	4.16 (.56)	
Primary School (7 years)	4.70	4.26 (.54)	4.34 (.58)
Primary School (8 years)	4.90	4.63 (.54)	
Primary School (9 years)	5.00	5.00 (.68)	
Primary School (10 years)	5.41	5.13 (.94)	5.13 (.81)
Primary School (11 years)	5.40	5.28 (.78)	
Secondary School (12 years)	5.50	5.30 (.88)	
Secondary School (13 years)	6.10	5.89 (.84)	5.46 (.85)
Secondary School (14 years)	6.00	5.51 (.83)	
Secondary School (15 years)	6.10	5.82 (.81)	
Secondary School (16 years)	6.30	5.75 (.87)	5.83 (.84)
Secondary School (17 years)		5.91 (.86)	

Table 3
Number of participants, gender (M / F), mean of years, of years of education, of MMSE, and of direct digit spans (standard deviations in parenthesis) by group

Group	Gender: Male (M)/ Female (F)	Mean of years	Mean of years of education	Mean of MMSE*	Mean of direct digit span
AD (N= 25)	7 / 18	73.48 (4.39)	7.76 (2.91)	20.36 (2.18)	4.20 (.65)
fvFTD (N= 9)	5 / 4	65.22 (6.59)	15.67 (3.39)	26.67 (2.33)	4.22 (.83)
C (N= 25)	6 / 19	72.72 (4.59)	7.12 (1.74)	27.68 (2.14)	4.44 (.76)

* Folstein, Folstein, & McHugh (1975)

However, the fvFTD patients' digit span (*M*= 4.22, *SD*= 0.83) was similar to the youngest groups (5-year-olds, [*t* (9.28)= - 1.60, two-tail, *p*= .143]; 6-year-olds [*t* (9.51)= - 0.23, two-tail, *p*= .823].

Discussion

As found in other studies (i.e., Engle & Marshall, 1983; Gathercole & Alloway, 2008), digit span increases throughout childhood up to adolescence; however, the present study reveals that digit span continues to expand until at least age 17 in a Spanish population, as opposed to the Anglo-Saxon data, according to which, by age 15, digit span has reached levels similar to those of adulthood—that is, a span of approximately 7 digits, with a mean of 6.7 by age 15 (Gathercole & Alloway, 2008; Isaacs & Vargha-Khadem, 1989).

It is also remarkable that the digit span shown in our study is, in general terms, lower than the one found for children in English studies (i.e., Isaacs & Vargha-Khadem, 1989). This difference in the developmental pattern of verbal span could be due to the word length effect. Baddeley et al., (1975) formulated that memory span was affected by lists which contained long words, with regard to lists containing short words. This effect has been related to subvocal rehearsal and recall processes. In the first case, it is understood that the greater the word length, the longer it takes to perform the rehearsal and, therefore, the easier it is to lose information during the rehearsal of a succession of long words (Baddeley et al., 1975). Moreover, the second case states that the longer it takes to utter a word (within a sequence), the greater the chance that the stored information will fade before fully recalling the complete sequence of words (Cowan et al., 1994). Overall, both effects could explain the differences found between Anglo-Saxon study and ours, as Spanish digits are longer (most of them are composed of two syllables, e.g., 'cuatro', 'cinco', 'siete', etc.) than English digits (most of which consist of just one syllable, e.g., 'one', 'two', 'three', etc.) (see also Ellis & Hennely, 1980; Naveh-Benjamin & Ayres, 1986).

In this line, if the word length effect is related to the process of subvocal rehearsal, which does not appear until age 7, then before this age, one would not expect such an effect and, therefore, differences between English data and ours should not appear until age 7 or 8. In this sense, several studies show a digit span of approximately 4 digits for children between ages 5 and 6 (Alloway, Gathercole, & Pickering, 2006; Engle & Marshall, 1983), which is congruent with the results found in our study. This equivalence in digit span, in spite of the differences in word length, suggests that, at these ages, the subvocal rehearsal is not yet present. On the contrary, our results differ from Anglo-Saxon data (i.e., Engle & Marshall, 1983; Isaacs & Vargha-Khadem, 1989) from age 7 and 8 onward, probably due to the rise of subvocal rehearsal at these ages and, therefore, to the presence of the above-mentioned word length effect. As an example**,** Engle and Marshall (1983) carried out a study to compare the development of digit span by three groups: first graders (mean age of 6.8), sixth graders (mean age of 11.9) and adults (mean age of 20.7). The Anglo-Saxon data shown in this study and data from ours are similar in 6-year-old children (4.1 and 4.16 respectively), whereas differences clearly appear when comparing both data in 11-year-old children: a mean of 6.3 digit span for English children, which matches Isaacs and Vargha-Khadem's (1989) data (6.1 digit span at age 11), towards a mean of 5.28 digit span found in our study at age 11 or a mean of 5.40 following the WISC-IV data for Spanish population at the same age.

Besides the word length effect on the repetition process, one could speculate about other strategies that underlie the working memory to explain span differences between different spoken language populations, such as recoding or chunking. For example, when having to remember a code or a record locator flight, associations between each letter with a town or a country are commonly used strategies. In Spain, the words that are most frequently associated are long words with three or four syllables (for example, Barcelona for «B», Italia for «I», or «Pamplona» for P), a strategy that probably results in a «word length effect» and in a poorer memory span performance compared to short-word associations, whereas Anglo-Saxon subjects are used to spelling the words since childhood. In the same line, it would be interesting to explore the manner in which digits are elaborated and whether there are differences between populations when chunking or coding that could explain intercultural differences in digit span.

Moreover, a comparison between the Spanish WISC-IV data and the results of our study on 6- to 16-year-old children can be established. Although the digit span is slightly higher in almost all age groups of the WISC-IV, the aim of this comparison is to observe the developmental pattern of span shown in both studies. In this sense, the WISC-IV data show a pattern of development similar to the digit span reflected in our study: the verbal span seems to increase during childhood and adolescence. Having included a group of 5-year-old participants in this study allows the comparison between very young children, finding a great improvement in digit span by age 6. On the other hand, it could be interesting to investigate whether this progression continues from age 17 onward. Data from the Spanish version of the Wechsler Adult Intelligence Scale-III (WAIS-III; Wechsler, 1997), which is applied as of age 16, have been examined for this study, finding that the group of 16- to 19-year-old youngsters presents a mean of 6.47 in their digit span. Although the results in this scale are shown by periods of age groups, and it is not possible to know the differences in means by age, the fact that mean span between ages 16 and 19 exceeds 15-year-old children's span (6.10 according to WISC-IV) and even the WISC-IV digit span at age 16 (6.30), suggests that there is an increase in subsequent years.

Assessing specific cognitive abilities not only at young ages, but also at older ages (i.e., 13- to 20-year-old groups), may be useful in order to determine at what point changes occur throughout the lifespan. Future comparisons between the acquisition and development of digit span and the course they follow in healthy elderly people and in patients with dementia could contribute to reach an integrated perspective of the research carried out in developmental psychology as well as in aging psychology and neuropsychology. In this sense, the results of this study could be compared with those obtained in a study conducted by Sebastian and Hernández-Gil (2010) in which digit span was assessed in healthy elderly, AD patients, and fvFTD patients. Generally, it was found that the digit span of the healthy elderly is similar to that of 7-year-old children, showing a clear effect of age, whereas the digit span found in AD and fvFTD patients is similar to that of 6-year-old children, and no significant differences are found between the healthy elderly, and AD or fvFTD patients. This fact may suggest that the capacity of the phonological loop is affected by age and not so much by dementias.

Acknowledgements

This work was supported by the Dirección General de Investigación Científica y Técnica of the Spanish Ministry of Science and Technology (grant number BSO2003-02429). We should like to thank Dr. Rosa Elosua and Gemma de la Torre for their help with the administration of the tasks, as well as Dr. Virginia Navascués for her help with the English version.

References

Alloway, T.P., Gathercole, S.E., & Pickering, S.J. (2006). Verbal and visuospatial short-term and working memory in children: Are they separable? *Child Development, 77,* 1698-1716.

Atkinson, R.C., & Shiffrin, R.M. (1968). Human memory: A proposed system and its control processes. In K.W. Spence & J.T. Spence (Eds.), *The Psychology of Learning & Motivation, vol. II* (pp. 89-122). New York: Academic Press.

Baddeley, A.D. (2000). The episodic buffer: A new component of working memory? *Trends in Cognitive Sciences, 4*, 417-423.

Baddeley, A.D., Eysenck, M.W., & Anderson, M.C. (2009). *Memory*. Hove, UK: Psychology Press.

Baddeley, A.D., & Hitch, G. (1974). Working memory. In G.H. Bower (Ed.), *The Psychology of Learning and Motivation, vol. VIII* (pp. 47-89). New York: Academic Press.

Baddeley, A.D., Thomson, N., & Buchanan, M. (1975). Word length and the structure of short-term memory. *Journal of Verbal Learning and Verbal Behavior, 14,* 575-589.

Case, R.D., Kurland, D.M., & Goldberg, J. (1982). Operational efficiency and the growth of short-term memory span. *Journal of Experimental Child Psychology, 33,* 386-404.

Cowan, N., Keller, T.A., Hulme, C., Roodenrys, S., McDougall, S., & Rack, J. (1994). Verbal memory span in children: Speech timing cues to the mechanisms underlying age and word length effects. *Journal of Memory and Language, 33,* 234-250.

Davidson, M.C., Amso, D., Anderson, L.C., & Diamond, A. (2006). Development of cognitive control and executive functions from 4-13 years: Evidence from manipulations of memory, inhibition, and task switching. *Neuropsychologia, 44,* 2037-2078.

Diamond, A. (2006). The early development of executive functions. In E. Bialystok & F.I.M. Craik (Eds.), *Lifespan cognition. Mechanism of change* (pp. 70-95). New York: Oxford University Press.

Ellis, N.C., & Hennelly, R.A. (1980). A bilingual word-length effect: Implications for intelligence testing and the relative ease of mental calculation in Welsh and English. *British Journal of Psychology, 71*, 43-52.

Engle, R.E., & Marshall, K. (1983). Developmental changes in digit span result from acquisition strategies. *Journal of Experimental Child Psychology*, *36*, 429-436.

Folstein, M.F., Folstein, S.E. & McHugh, P.R. (1975). 'Mini-mental state'. A practical method for grading the cognitive state of patients for the clinician. *Journal of Psychiatry Research*, *12*, 189-198.

Fry, A.F., & Hale, S. (1996). Processing speed, working memory, and fluid intelligence: Evidence for a developmental cascade. *Psychological Science, 7,* 237-241.

Gathercole, S.E. (2008). Working memory. In J.H. Byrne (Ed.), *Concise learning and memory* (pp. 149-167). London: Elsevier.

Gathercole, S.E., & Alloway, T.P. (2008). *Working memory and learning. A practical guide for teachers*. London: Sage Publications.

Hitch, G.J. (2006). Working memory in children. In E. Bialystok & F.I.M. Craik (Eds.), *Lifespan cognition. Mechanism of change* (pp. 112-127). New York: Oxford University Press.

Hitch, G.J., & Halliday, M.S. (1983). Working memory in children. *Philosophical Transactions of the Royal Society of London, B, 302*, 324-340.

Hitch, G.J., Towse, J.N., & Hutton, U. (2001). What limits children's working memory span? Theoretical accounts and application to scholastic development. *Journal of Experimental Child Psychology, 77,* 128-137.

Hulme, C., & Tordoff, V. (1989). Working memory development: The effects of speech rate, word length, and acoustic similarity on serial recall. *Journal of Experimental Child Psychology, 47*, 72-78.

Isaacs, E.B., & Vargha-Khadem, F. (1989). Differential course of development of spatial and verbal memory span: A normative study. *British Journal of Developmental Psychology, 7,* 377-380.

Naveh-Benjamin, M., & Ayres, T.J. (1986). Digit span, reading rate, and linguistic relativity. *Quarterly Journal of Experimental Psychology, 38,* 739-751.

Sebastian, M.V., & Hernández-Gil, L. (2010). A comparison of memory and executive functions in Alzheimer disease and frontal variant of frontotemporal dementia. *Psicothema, 22,* 424-429.

Wechsler, D. (1997). *Wechsler Adult Intelligence Scale Third Edition (WAIS-III)*. San Antonio Texas: The Psychological Corporation [Spanish Version, Madrid: TEA Ediciones, 1999].

Wechsler, D. (2003). *Manual for the Wechsler Intelligence Scale for Children-Fourth Edition (WISC-IV)*. San Antonio, Texas: The Psychological Corporation [Spanish Version, Madrid: TEA Ediciones, 2005].