International Journal of Psychology
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/pijp20

# Digit Span: Effect of education and culture

Feggy Ostrosky-Solís [a] & Asucena Lozano [a]

[a] Universidad Nacional Autónoma de México, Lomas de Reforma, Mexico

Available online: 23 Feb 2007

To cite this article: Feggy Ostrosky-Solís & Asucena Lozano (2006): Digit Span: Effect of education and culture, International Journal of Psychology, 41:5, 333-341

To link to this article: http://dx.doi.org/10.1080/00207590500345724

INTERNATIONAL JOURNAL OF PSYCHOLOGY, 2006, 41 (5), 333–341

Psychology Press
Taylor & Francis Group

# Digit Span: Effect of education and culture

**Feggy Ostrosky-Solís and Asucena Lozano**

*Universidad Nacional Autónoma de México, Lomas de Reforma, Mexico*

The Digit Span test is one of the most commonly used measures of immediate verbal recall, attentional capacity, and working memory in neuropsychological research and clinical evaluations. This test comprises two modalities, digits forward and digits backward. It has been established that age, education, and culture are important variables that affect performance on this test. The purposes of this study were as follows. First, performance on digit span in a Spanish-speaking sample was analysed to establish appropriate age and educational ranges in which data from the Digit Span test can be best analysed, and to determine the contribution of age and education to performance on the digit span forward and backward. Second, different studies on digit span were compared and reviewed in order to identify differences in terms of the variables of age, education, and culture. This study evaluated 2574 Spanish-speaking subjects and three studies were included in the cross-cultural analysis. Scores from the Spanish-speaking sample were matched with the data presented by the other studies according to age and level of education. Results showed that the stronger predicting variable in the Spanish-speaking sample was the level of education, both for digits forward and backward. Regarding culture, differences were found among the studies on digit span for both the forward and backward conditions. It can be argued that learning to read and write affects the development or usage of the abilities measured by the Digit Span task, and that cultural variables such as language and quality of education might also contribute to the differences found between countries.

L'épreuve de «*Digit Span*» est une des mesures de rappel verbal immédiat, de capacité attentionnelle et de mémoire de travail les plus fréquemment utilisées dans la recherche neuropsychologique et dans les évaluations cliniques. Ce test comporte deux modalités: les digits en avant (forward) et ceux en arrière (backward). Il a été établi que l'âge, l'éducation et la culture sont des variables importantes qui affectent la performance à ce test. Les objectifs de cette étude étaient les suivants: Premièrement, analyser la performance à l'épreuve de la digit span dans un échantillon d'hispanophones, ceci dans le but d'établir l'écart d'âge et d'éducation dans lequel les données du test du digit span peuvent être analysées et de déterminer la contribution de l'âge et de l'éducation à la performance au digit span en avant et en arrière; Deuxièmement, réviser une comparaison entre différentes études sur le digit span afin de déterminer s'il existe des différences quant aux variables d'âge, d'éducation et de culture. L'échantillon se compose de 2574 participants hispanophones qui ont été évalués dans le cadre de cette étude et 3 études ont été incluses dans l'analyse trans-culturelle. Les scores de l'échantillon hispanophones ont été appariés avec les données présentées par les autres études par rapport à l'âge et à l'éducation. Les résultats ont indiqué que, dans l'échantillon hispanophone, le prédicteur le plus important était le niveau d'éducation à la fois pour les digits en avant et pour ceux en arrière. En ce qui concerne la culture, des différences ont été observées entre les études sur le digit span tant pour les conditions en avant que pour celles en arrière. Il est possible d'argumenter que l'apprentissage de la lecture et de l'écriture affecte le développement ou l'usage des habiletés mesurées par la tâche du digit span. De plus, les variables culturelles comme le langage et la qualité de l'éducation peuvent aussi contribuer aux différences entre les pays.

La prueba de retención de dígitos es una de las más utilizadas para medir memoria verbal inmediata, capacidad atencional y memoria de trabajo en evaluaciones neuropsicológicas tanto en el ambiente experimental como clínico. Esta prueba incluye dos modalidades, retención de dígitos en progresión y en regresión. Se ha establecido que la educación y la cultura son variables importantes que afectan el desempeño en esta prueba. Los objetivos de este estudio fueron: primero, analizar en una muestra de sujetos hispanohablantes la prueba de retención de dígitos para establecer los rangos de edad y escolaridad más apropiados para analizar el desempeño y determinar la contribución de la edad y escolaridad al puntaje de dígitos en progresión y regresión;

Correspondence should be addressed to Feggy Ostrosky-Solís, PhD, Universidad Nacional Autónoma de México, Rivera de Cupia 110-71, Lomas de Reforma, México, DF 11930 (E-mail: feggy@servidor.unam.mx).



http://www.psypress.com/ijp DOI: 10.1080/00207590500345724

segundo, comparar diferentes estudios que utilizaron la prueba de retención de dígitos para determinar si existe alguna diferencia en el desempeño en términos de las variables de edad, educación o cultura. Se evaluaron 2574 sujetos hispanohablantes y se incluyeron 3 estudios para el análisis transcultural. La muestra de hispanohablantes fue pareada por edad y escolaridad con las muestras utilizadas por los otros estudios para hacer las comparaciones en el desempeño en esta prueba en diferentes países. Los resultados muestran que la variable predictora más importante en la muestra de sujetos hispanohablantes es la escolaridad para dígitos en progresión y dígitos en regresión. En relación a la cultura, se encontraron diferencias en el desempeño entre los diferentes estudios revisados tanto en dígitos en progresión como en regresión. Se concluye que el aprendizaje de la lectoescritura afecta el desarrollo y uso de aquellas habilidades que implica la prueba de retención de dígitos y que variables culturales como el idioma y la calidad de la educación contribuyen a las diferencias encontradas entre diferentes estudios.



The Digit Span test included in the Wechsler batteries (intelligence and memory) is one of the most commonly used measures of immediate verbal recall and attentional capacity in neuropsychological research and clinical evaluations. In this test subjects are exposed to larger amounts of information, with instruction to indicate how much of the given information they remembered by immediately repeating what they heard. This test comprises two modalities, Digits Forward and Digits Backward. A series of strings of digits are read to subjects who are then asked to repeat them orally in the correct sequence (either forward or backward). The number of digits in each string increases from 3 to 9 forward and 2 to 8 backward. The test is discontinued if the subject fails two consecutive trials. Total score corresponds to the maximum number of digits the subject is able to repeat correctly.

These modalities of digit span require an adequate auditory attention and both depend on a short-term retention capacity. Recently, it has been argued that the Digit Span tests implicate verbal working memory (Baddeley, 2000). Baddeley and Hitch (1974) proposed a model in which working memory is comprised of a supervisory controlling system (the central executive) aided by two peripheral "slave" systems: the phonological (or articulatory) loop, involved in the temporary storage and maintenance of speech-based material; and the visuospatial sketchpad for visual and spatial information. The central executive is conceptualized as an attention control system responsible for strategy selection, control, and coordination of cognitive processes. Within this framework, forward digit span would be managed primarily by the phonological loop, while more extensive involvement of the central executive is expected to occur when the digits are repeated in the reversed order, as the number strings have to be remembered and then reversed in order to give the correct answer.

In clinical populations this test has shown to be more vulnerable to left-hemisphere damage than to right or diffuse damage (Lezak, 1995). Other studies have found impaired backward span performance in clinical samples, such as TBI (Curtiss, Vanderploeg, Spencer, & Salazar, 2001) and chronic fatigue syndrome (Dobbs, Dobbs, & Kiss, 2001).

Some studies have shown conflicting results regarding the influence of education and age on digit span performance. Ardila, Ostrosky-Solís, Rosselli, and Gómez (2000a) evaluated a sample of 883 subjects ranging from 16 to 85 years of age; with 0 to 24 years of education. They found that subjects with little or no education tend to maintain the same level of performance for digits backward across different age ranges, whereas older subjects with 10 and more years of education show a decrement in performance. The authors concluded that performance on specific cognitive domains will be affected differentially by the interaction of both education and age. Other studies have pointed out that age is a stronger predictive variable than education on the Digit Span test. This result was obtained from data taken from the normative sample of the Wechsler Memory Scale (Hester, Kinsella, & Ong, 2004). Age-related decrease has also been described for the forward and backward conditions of the Digit Span task. In a metanalysis of 14 studies by Babcock and Salthouse (1990), decreases for the backward digit span performance were greater than in performance of the forward condition (14% and 8% respectively). These results are in accordance with clinical reports that the greater the age, the greater the deficits shown in the backward span task (Lezak, 1995). However, other studies have not found such an effect, and report the same rate of decline for both digits forward and backward (Myerson, Emery, White, & Hale, 2003; Wilde, Strauss, & Tulsky, 2004).

Recently, another variable that affects performance in neuropsychological testing has been the subject of much attention. Cross-cultural research has focused on comparisons between different neuropsychological tests in different cultures. Culture can be defined as the way of life of a self-regulating human group, and includes values, attitudes, and beliefs that are made manifest in speech, behaviours, laws, and customary practices (Harris, 1983; Shweder, 1999). Clinical neuropsychology has looked to develop suitable measures for testing in different cultural contexts; the first attempts considered the nonverbal test to be more appropriate due to the "supposed" culture-free characteristics of nonverbal abilities. However, it has been demonstrated that such abilities are equally, if not more greatly, affected by culture than verbal skills (Rosselli & Ardila, 2003).

On digit span, there are few articles regarding this issue. Reynolds, Willson, and Ramsey (1999) evaluated white American, Mexican American, and Native American (Papagos) children from 6 to 16 years and from grade 1 to 9 with the WISC-R. Differences were found on digit span only between the white American and Papagos children. Authors relate this finding to the development of specific abilities that depend upon what certain cultures determine to be important. Another possible explanation is unfamiliarity with testing procedures in the Papagos children.

Another comparison among different countries on the Digit Span test was made by Nell (2000). He shows data from 12 countries (in Europe, North America, Australasia, South America, and South Africa) for the forward and backward conditions according to some age and educational ranges. Overall, it appears that the average of the number of digits correctly repeated across countries is very similar if the above-mentioned variables are held constant, especially among European countries, whereas there seem to be differences if a wide range of schooling is considered. Furthermore, the Digit Span test has been included in a core test battery for adults with fewer than 12 years of education that is designed to be applicable in different countries, cultures, and languages (Nell, 2000).

However, it has been shown that the effect of education on neuropsychological test performance is not a linear one. Instead, it represents a negatively accelerated curve tending to a plateau (Ardila, 2000; Ostrosky-Solís, Ardila, Rosselli, López-Arango, & Uriel-Mendoza, 1998). The differences between subjects with 0, 1, 2, 3, or 4 years of education are greater than those expected between subjects with 5 to 9 years of education, and even fewer differences are expected between subjects with more than 10 years of education. Thus, important characteristics in the digit span performance among subjects might be lost due to the use of a wide educational range.

Therefore, the purpose of this study was twofold. First, performance on digit span in a Spanish-speaking sample was analysed in order to establish appropriate age and educational ranges in which data from the Digit Span test can be best analysed. Second, a comparison among different studies on digit span will be reviewed in order to identify if any differences exist in terms of the variables of age, education and culture.

## METHOD

### Participants (Mexican sample)

For this study, 2574 subjects agreed to be evaluated (male = 967 and female = 1607). Sample age ranged from 16 to 96 years (mean age = 42.09, *SD* = 24.12) and level of education ranged from 0–24 years (mean level of education = 6.42 years, *SD* = 5.55). Illiterate subjects included in this study did not attend school due to lack of opportunity (lack of schools or socioeconomic reasons). Some of them could write either their initials or their name, but were unable to recognize or write other letters of the alphabet or to read single words. All participants were functionally independent, and those with any psychiatric or neurological impairment were discarded by taking a brief clinical history.

### Procedure

Total scores for digits backward were taken from the NEUROPSI neuropsychological test battery (Ostrosky-Solís, Ardila, & Rosselli, 1999) and the NEUROPSI Attention & Memory battery (Ostrosky-Solís et al., 2003). Total scores for digits forward were obtained from the NEUROPSI Attention & Memory battery. Testing procedure for the Digit Span task was done according to the standard administration, that is, strings of digits are read to subjects at a rate of 1 per second and the subject is asked to repeat them orally in the correct sequence (either forward or backwards). The number of digits in each string increases from 3 to 9 forward and from 2 to 8 backward. The test is discontinued if the subject fails two consecutive trials. Total score corresponds to the maximum number of digits the subject is able to repeat correctly.

In order to make comparisons between countries, a search of articles was conducted in several computerized databases: PsycINFO, Science direct, EBSCO, and Swetwise. The following keywords were used: digit span, attention span, digits forward, digits backward, and normative data. Only those studies published in peer-reviewed journals were considered. The selected studies were either normative or studies in which a control group of normal participants was used. Although a great number of studies have been published regarding normative or experimental data for the Digit Span test, only those containing the number of subjects, mean, and standard deviation on performance for digits forward and digits backward in each age range and educational level were considered in order to compare the means.

## Statistical analyses

Two sets of analyses were done for this study. First, data from the Mexican sample on the Digit Span test was used to establish which age and educational ranges were the most appropriate to use according to subject's performance on this test. A stepwise regression analysis was performed to obtain the contribution of both education and age to the Digit Span score (forward and backward).

The second analysis was carried out comparing the means on digits forward and backward from the published studies in different countries to establish whether any difference exists between subjects' performance. The Mexican sample was paired according to the age and educational level used in each of the studies. The means of digits forward and backward were analysed for each of the studies with a *t*-test using the Computerized Program for Metanalysis (Schwarzer, 1994).

# RESULTS

## Mexican data on Digit Span tests

### Digits forward

Table 1 presents the demographic characteristics of the sample. A total of 485 participants were evaluated (173 men and 312 women). Mean age was 42.98 ($SD$ = 20.16) and mean years of education was 9.51 ($SD$ = 5.6). The mean number of digits correctly repeated was 5.35 ($SD$ = 1.15).

In order to make a finer analysis of the sample's performance on the Digits Forward test, age and years of education were grouped into ranges of 5 years. An analysis of variance and post hoc tests were used to identify age and educational ranges in which there were differences in the performance on the Digits Forward test. Results showed that the sample could be divided into three educational ranges: 0 to 2 years of education, 3 to 7 years, and >8 years. Age ranges were established as follows: 16 to 30 years, 31 to 74 years, and >75 years. Means and standard deviation of digits forward in each of these ranges are shown in Table 2.

As can be observed, in the educational range of 0 to 2 years, performance is stable across different age ranges, whereas in the 3 to 7 and > 8 years of education groups, performance decreases in the older age range.

A stepwise regression analysis was performed to obtain the contribution of age and education to performance on the digit forward test. These

**TABLE 1**
Digits forward: Characteristics of the sample ($n$=485)

| | *Sex* | | *Age* | | *Education* | | *Digits forward* | |
|---|---|---|---|---|---|---|---|---|
| *n* | *Male* | *Female* | *X* | *SD* | *X* | *SD* | *X* | *SD* |
| 485 | 173 | 312 | 42.98 | (20.16) | 9.51 | (5.6) | 5.35 | (1.15) |

**TABLE 2**
Means and standard deviations of digits forward according to educational and age ranges: Mexico ($n$=485)

| | *Age* | | | | | |
|---|---|---|---|---|---|---|
| | *16–30* | | *31–74* | | *75–90* | |
| *Years of education* | *X* | *SD* | *X* | *SD* | *X* | *SD* |
| 0–2 | 4.36 | (1.46) | 4.20 | (0.99) | 4.50 | (0.81) |
| 3–7 | 5.50 | (1.00) | 5.00 | (1.00) | 4.63 | (0.95) |
| 8–22 | 5.94 | (0.97) | 5.58 | (0.97) | 4.57 | (1.13) |

variables were entered as the independent variables, and the score for digits forward was the dependent variable. The percentage of variance explained by education was 25% and it was 14% for age. The equation obtained was:

$$\text{Digits forward} = 4.785 + \text{education}(0.092) + \text{age}(0.007)$$

### *Digits backward*

Table 3 presents the demographic characteristics of the sample. A total of 2089 participants were evaluated (794 men and 1295 women). Mean age was 49.32 ($SD$ = 20.68) and mean years of education was 6.79 ($SD = 5.97$). The mean number of digits correctly repeated was 3.23 ($SD = 1.24$).

As in the digits forward sample, age and years of education were grouped into ranges of 5 years and an analysis of variance and post hoc tests were used to identify age and educational ranges in which there were differences in performance on the Digits Backward test. Results showed that the sample could be grouped into the following educational ranges: illiterates, 1 to 6 years of education, and >7 years. Age can also be grouped into three ranges: 16–30 years, 31–74 years, and >75 years. Means and standard deviation of digits forward for each of these ranges are shown in Table 4. Results show that illiterates and the 1 to 6 years educational ranges maintain a stable performance across the three age ranges, whereas subjects with more than 7 years of education tend to show a decrease in the mean score as age increases.

A stepwise regression analysis was also performed to obtain the contribution of age and education to the digit backward score. These variables were entered as the independent variables, and the score for digits backward was the dependent variable. Education was the only variable left in the model; it explained 31% of the variance for the total score. The equation obtained was:

$$\text{Digits backward} = 2.440 + \text{education}\ (0.117)$$

## Cross-cultural comparisons on digit span

A total of three studies were considered for comparison purposes: a study from the USA (Powell & Hiatt, 1996), one from Denmark (Öberg, personal communication), and a table reported by Nell (2000). In Nell's table, data from 12 countries (in Europe, North America, Australasia, South America, and South Africa) for the forward and backward conditions, for some age and educational ranges, is presented, but only those studies that included means of age and education were considered. Table 5 shows mean age and educational levels of the samples used in each study. The Mexican sample was paired according to these data, and the mean score for digits forward and backward was obtained.

Table 6 shows means and standard deviations of digits forward for each country and for the Mexican sample. As can be seen, there were differences between the Mexican sample and Poland, Venezuela, South Africa 1, South Africa 4, and South Africa 6.

Table 7 shows means and standard deviations of digits backward for each country and for the Mexican sample. All countries showed significant

**TABLE 3**
Digits backward: Characteristics of the sample ($n$=2089)

| | *Sex* | | *Age* | | *Education* | | *Digits backward* | |
|---|---|---|---|---|---|---|---|---|
| *n* | *Male* | *Female* | *X* | *SD* | *X* | *SD* | *X* | *SD* |
| 2089 | 794 | 1295 | 49.32 | (20.68) | 6.79 | (5.97) | 3.23 | (1.24) |

**TABLE 4**
Digits backward ($n$=2089): Means and standard deviations by age and level of education

| | *Age* | | | | | |
|---|---|---|---|---|---|---|
| | *16–30* | | *31–74* | | *75–90* | |
| *Years of education* | *X* | *SD* | *X* | *SD* | *X* | *SD* |
| Illiterates | 2.34 | (1.23) | 2.38 | (1.16) | 2.22 | (0.84) |
| 1–6 | 2.78 | (1.24) | 2.93 | (1.03) | 2.74 | (0.92) |
| 7–22 | 4.14 | (1.00) | 3.96 | (1.00) | 3.58 | (0.95) |

**TABLE 5**
Characteristics of the samples used in each study considered for comparison with the Mexican sample: Means and standard deviations of age and education are presented

| *Country* | *n* | *Age years* | *Education years* |
|---|---|---|---|
| Austria[a] | 19 | 26–35 | 8–10 |
| France[a] | 24 | 26–35 | 8–10 |
| Hungary[a] | 18 | 26–35 | 8–10 |
| Italy[a] | 112 | 26–35 | 8–10 |
| Netherlands[a] | 35 | 26–35 | 8–10 |
| Poland[a] | 28 | 26–35 | 8–10 |
| China[a] | 23 | 35.4 (8.4) | 6.2 (2.7) |
| Venezuela[a] | 47 | 35 (11) | 8 (3) |
| South Africa 1[a] | 100 | 24 (4.2) | 13–14 |
| South Africa 2[a] | 140 | 25 (3.3) | 9–12 |
| South Africa 2[a] | 63 | 25 (3.3) | 13–15 |
| South Africa 3[a] | 247 | 36 (10) | 5 (2.9) |
| South Africa 4[a] | 54 | 46 (9) | 6 (3.5) |
| South Africa 5[a] | 15 | 35–50 | 6 (1.7) |
| South Africa 6[a] | 20 | 41 (8.2) | 5 (8.2) |
| Denmark | 49 | 70.68 (6.08) | 9.3 (1.7) |
| USA | 80 | 24.3 (8.8) | 14.2 (2.4) |

[a]Taken from Nell (2000).

differences in the mean scores compared to the Mexican sample, except studies 4, 5, and 6 from South Africa.

## DISCUSSION

The first objective of this study was to establish age and educational ranges through which the effect of these variables on Digit Span test performance could best be analysed. As can be seen from the tables and the results from the regression analysis, these variables do not affect performance equally. In the digits forward, no differences are found between illiterates and subjects with 1 and 2 years of education, whereas in the backward condition, no merging can be done because there are significant differences among illiterates and subjects with 1 to 6 years of education. Furthermore, many studies have pointed out that age is the main variable that explains an adequate performance on the Digit Span task in either the forward or backward conditions. However, in this study the stronger variable is education, followed by a small contribution from age in the forward condition; this variable was excluded from the regression model in the digits backward condition. This effect may be due to the educational ranges included in the studies, most of which merge subjects with little or no education and subjects with up to 8 years of formal schooling (Groeger, Field, & Hammond, 1999; Hester et al., 2004; Myerson et al., 2003; Wilde et al., 2004), or only include subjects with a high level of education (Powell & Hiatt, 1996; Wilde & Strauss, 2002).

In the higher level of education (8 to 22 years) it is observed that performance decreases in the older adults; this tendency has been seen in most studies on digit span (Groeger et al., 1999; Hester et al., 2004; Myerson et al., 2003; Wilde et al., 2004). It has been proposed that this effect is in accordance with research indicating that working memory

**TABLE 6**
Comparisons with *t*-test of total scores on digits forward among samples of other countries and Mexico: The Mexican sample was paired according to age and level of education to the sample of the different countries (*X*=mean, *SD*=standard deviation)

| | *Digits forward* | | | *Digits forward: Mexico* | | | |
|---|---|---|---|---|---|---|---|
| *Country* | *X* | *SD* | *n* | *X* | *SD* | *n* | *t* |
| Austria | 7.7 | (1.9) | 19 | 5.3 | (0.93) | 20 | 4.969** |
| France | 6.6 | (2.0) | 24 | 5.3 | (0.93) | 20 | 2.837** |
| Hungary | 6.1 | (0.9) | 18 | 5.3 | (0.93) | 20 | 2.693** |
| Italy | 6.7 | (1.9) | 112 | 5.3 | (0.93) | 20 | 5.095** |
| Netherlands | 6.1 | (1.7) | 35 | 5.3 | (0.93) | 20 | 2.255** |
| Poland | 5.4 | (1.1) | 28 | 5.3 | (0.93) | 20 | 0.340 |
| China | 6.8 | (3.5) | 23 | 5.4 | (1.01) | 27 | 1.853** |
| Venezuela | 5.2 | (2.0) | 47 | 5.3 | (0.83) | 45 | −0.315 |
| South Africa 1 | 6.2 | (0.9) | 100 | 6.0 | (1.16) | 18 | 0.694 |
| South Africa 2 | 7.4 | (2.3) | 140 | 5.5 | (0.91) | 25 | 7.135** |
| South Africa 2 | 7.9 | (2.0) | 63 | 5.6 | (1.03) | 25 | 7.066** |
| South Africa 3 | 4.8 | (1.0) | 247 | 5.4 | (0.82) | 11 | 2.350** |
| South Africa 4 | 5.2 | (1.0) | 54 | 5.1 | (0.96) | 37 | 0.438 |
| South Africa 5 | 4.3 | (1.7) | 15 | 5.1 | (0.90) | 31 | 1.710** |
| South Africa 6 | 4.5 | (0.9) | 20 | 4.8 | (0.98) | 41 | 1.186 |
| Denmark | 6,02 | (0.85) | 49 | 5.19 | (1.10) | 27 | 3.401** |
| USA | 7.3 | (1.14) | 80 | 5.8 | (0.89) | 25 | 6.851** |

**$p$>.05.

**TABLE 7**

Comparisons with *t*-test of total scores on digits backward among samples of other countries and Mexico: The Mexican sample was paired according to age and level of education to the sample of the different countries (*X*=mean, *SD*=standard deviation)

| | *Digits backward* | | | *Digits backward: Mexico* | | | |
|---|---|---|---|---|---|---|---|
| *Country* | *X* | *SD* | *n* | *X* | *SD* | *n* | *t* |
| Austria | 6.7 | (1.3) | 19 | 3.7 | (0.91) | 27 | 8.674** |
| France | 5.8 | (2.3) | 24 | 3.7 | (0.91) | 27 | 4.190** |
| Hungary | 4.5 | (0.9) | 18 | 3.7 | (0.91) | 27 | 2.908** |
| Italy | 4.5 | (2.1) | 112 | 3.7 | (0.91) | 27 | 3.022** |
| Netherlands | 6.4 | (1.9) | 35 | 3.7 | (0.91) | 27 | 7.381** |
| Poland | 5.0 | (0.9) | 28 | 3.7 | (0.91) | 27 | 5.325** |
| China | 4.6 | (1.6) | 23 | 3.4 | (0.88) | 35 | 3.285** |
| Venezuela | 4.3 | (2.0) | 47 | 3.5 | (0.97) | 107 | 2.610** |
| South Africa 1 | 5.0 | (0.9) | 100 | 4.0 | (0.82) | 23 | 5.175** |
| South Africa 2 | 5.6 | (2.2) | 140 | 3.9 | (0.88) | 44 | 7.442** |
| South Africa 2 | 6.3 | (2.0) | 63 | 4.1 | (0.85) | 38 | 7.659** |
| South Africa 3 | 3.3 | (1.1) | 247 | 3.1 | (1.12) | 81 | 1.400** |
| South Africa 4 | 3.3 | (1.0) | 54 | 3.1 | (0.90) | 113 | 1.247 |
| South Africa 5 | 2.7 | (1.1) | 15 | 3.3 | (0.98) | 56 | 1.918 |
| South Africa 6 | 2.8 | (1.4) | 20 | 2.7 | (1.13) | 272 | 0.312 |
| USA | 5.6 | (1.27) | 80 | 4.2 | (0.98) | 151 | 8.596** |

**$p > .05$.

declines with increasing age (Baeckman, Small, Wahlin, & Larsson, 2000; Salthouse, Fristoe, Lineweaver, & Coon, 1995). Hester et al. (2004) suggest that the efficiency of the central executive might be reduced due to an age-related limiting capacity of the amount of information that can be processed by the slave systems at one time, therefore affecting performance in the elderly.

Several studies have pointed out that illiterates underperform in neuropsychological tasks that require working memory and immediate verbal attention (Ostrosky-Solís et al., 1998, 1999), which are processes required by the Digit Span task. A possible explanation relates to the fact that illiterates and subjects with little formal schooling find the usual testing situation very unfamiliar (Reis & Castro-Caldas, 1997; Rosselli, Ardila, & Rosas, 1990). Poor performance might be accounted for by this unusual testing situation as well as by the effect of the acquisition or development of some cognitive strategies.

In accordance with previous data (Ardila, Rosselli, & Rosas, 1989; Reis, Guerreiro, García, & Castro-Caldas, 1995), there was a significant literacy effect on the Digit Span task. That is, the literates performed significantly better than the illiterate subjects. This task was sensitive not only to literacy but also to years of formal education, thus indicating that the latter is an important factor in influencing the cognitive processes required to perform the task. The literacy effect on digit span has also been investigated in terms of the influence of the magnitude component of digit representations. Reis et al. (1995) compared the performance of illiterates and literate subjects on a Digit Span task with digits smaller or larger than 5. Illiterates performed significantly worse on digits larger than 5 as compared to numbers smaller than 5, while this was not the case for the literate group.

It has been proposed that lack of schooling has an impact on the development of cognition; that is, formal education promotes an alternative way in which information can be conceptually processed, thus enhancing the acquisition of specific abilities essential to the development of a number of cognitive strategies. It may be argued that learning to read and write promotes the practice and reinforces the usage of these abilities and strategies, Ardila, Ostrosky-Solís, and Uriel-Mendoza (2000b) showed that illiterates who are taught to read and write improve their neuropsychological test performance, including the Digit Span task.

Petersson, Reis, and Ingvar (2001) applied a network analysis approach based on structural equation modelling (SEM) to study patterns of interactions between functionally specialized brain regions. They analysed the observed covariance structure in a PET data set from an auditory verbal repetition paradigm in literate and illiterate subjects. The results indicate that illiterate subjects show differences in attentional modulation of the language network and executive aspects of verbal working memory compared to literate subjects. This suggests that the language system would then be differently developed in the illiterates; the abilities implicated by the Digit Span task may not be fully developed in this group, so that they obtain lower scores than literate subjects and maintain the same level of performance across different age ranges. As Baddeley (1996, 2001) has pointed out, the Digit Span task would imply relatively little complex processing, determined more by storage than by executive functioning, but as the number of digits to be recalled increases, so does the recruitment of the phonological loop and the central executive. This would also explain poor performance among illiterates in the Digit Span task and the fact that, in the digits backward condition, no merging can be done between illiterates and subjects with 1 year of formal schooling. This condition would involve more attentional and executive resources, which illiterates do not possess, and even 1 year of schooling might provide enough training in these abilities to make a difference in performance of the test.

The second objective was to compare different studies of digit span to identify if there are any differences in terms of the variables of age, education, and culture. Recently, researchers have focused on the impact of culture on neuropsychological test performance. Few studies have addressed this issue regarding the Digit Span task. The results obtained in this study, comparing the total scores on digits forward and backward between different countries and a Mexican sample, show a difference that cannot be fully explained in terms of differences in age or years of schooling.

Some studies have suggested that differences in performance on the Digit Span task in different countries could be accounted for by the language spoken by the subjects. A cross-linguistic study by Naveh-Benjamin and Ayres (1986) found that digit span was larger for languages in which speech rate (estimated by reading speed) was faster. For instance, the mean of digit span for English was 7.2 and for Arabic it was 5.77. Studies of bilinguals have also shown that larger digit spans are obtained in the language in which speech rate is fastest (Chincotta & Hoosain, 1995; Chincotta & Underwood, 1996). Chincotta and Underwood (1997) examined the effect of articulatory suppression in order to clarify its influence on the discrepancies observed between different languages in this test. They visually presented series of digits that subjects had to repeat verbally after presentation. In the articulatory suppression condition, the legend *la-la* appeared on the screen 2 seconds prior to the sequences of digits, and subjects had to commence by articulating the suppression phrase. They found that when the articulatory suppression task is present during the Digit Span task, performance is equivalent among different languages. It is argued that under the articulatory suppression condition, the translation of visual stimuli into phonological codes is prevented by the disablement of the articulatory control process, reducing the contribution of the phonological loop.

The differences found in our comparisons might partially be accounted for by this effect of speech rate. However, this effect has only been shown in the digits forward condition and with bilingual subjects, thus the possible effect on monolingual subjects and in the backward condition remains unclear.

Another possible factor that may explain the differences observed in digit span performance across countries is that education can be considered as an element that includes both literacy and schooling. Viewed in this way, school is a subculture that dictates which abilities and attitudes the educational system should develop and reinforce and at what age (Ardila, 2000; Ardila et al., 2000b; Rosselli & Ardila, 2003). Although school promotes the acquisition of certain values and abilities regardless of the location, differences in the education system in terms of structure and quality might impact upon the development of certain cognitive abilities like verbal attention and working memory, thus affecting performance on a test that measures these abilities, such as Digit Span.

In conclusion, learning to read and write during childhood influences brain functional organization and behaviour, so the study of illiterates creates an opportunity to acquire knowledge regarding the interactions between neurobiological and cultural factors on cognitive development. Recently, there has been an enormous interest in the development of valid norms for illiterate populations for clinical purposes, cognitive research, and cross-cultural comparisons.Thus, the data obtained in this study suggest that in order to obtain meaningful norms for interpreting performance on the Digit Span task both in clinical and experimental settings, it is necessary to use narrower educational ranges when assessing subjects with wide educational attainment. On the other hand, with the available data it cannot be assumed that measures of verbal attention and working memory as assessed by the Digit Span task are equally developed in different contexts (i.e., cultures). This makes it necessary to generate and valid norms for each group to which this test is applied, and to consider the confounding effects of the relevant variables when assessing patients from a different cultural background to that of the examiner, in order to avoid a wrong diagnosis.

## REFERENCES


Ardila, A. (2000). Evaluación cognoscitiva en analfabetas. *Revista de Neurología*, *30*, 465–468.

Ardila, A., Ostrosky-Solís, F., Rosselli, M., & Gómez, C. (2000a). Age-related cognotive decline during normal aging: The complex effect of education. *Archives of Clinical Neuropsychology*, *15*, 495–513.

Ardila, A., Ostrosky- Solís, F., & Uriel-Mendoza, V. (2000b). Learning to read is much more than learning to read: A neuropsychologically-based learning to read method. *Journal of the International Neuropsychological Society*, *6*, 789–801.

Ardila, A., Rosselli, M., & Rosas, P. (1989). Neuropsychological assessment in illiterates: Visuospatial and memory abilities. *Brain and Cognition*, *11*, 147–166.

Babcock, R. L., & Salthouse, T. A. (1990). Effects of increased processing demands on age differences in working memory. *Psychology and Aging*, *5*, 421–428.

Baddeley, A. (1996). Exploring the central executive. *Quarterly Journal of Experimental Psychology: Human Experimental Psychology*, *49A*, 5–28.

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

Baddeley, A. (2001). Is working memory still working? *American Psychologist*, *56*, 851–864.

Baddeley, A., & Hitch, G. (1974). Working memory. In G. H. Bower (Ed.), *The psychology of learning and motivation*. San Diego: Academic Press.

Baeckman, L., Small, B. J., Wahlin, A., & Larsson, M. (2000). Cognitive function in very old age. In F. I. M. Craik (Ed.), *Handbook of aging and cognition*. Mahwah, NJ: Lawrence Erlbaum Associates Inc.

Chincotta, D., & Hoosain, R. (1995). Reading rate articulatory suppression and bilingual digit span. *European Journal of Cognitive Psychology*, *36*, 233–252.

Chincotta, D., & Underwood, G. (1996). Mother tongue, language of schooling and bilingual digit span. *British Journal of Psychology*, *87*, 193–208.

Chincotta, D., & Underwood, G. (1997). Digit span and articulatory suppression: A cross-linguistic comparison. *European Journal of Cognitive Psychology*, *9*, 89–96.

Curtiss, G., Vanderploeg, R. D., Spencer, J., & Salazar, A. M. (2001). Patterns of verbal learning and memory in traumatic brain injury. *Journal of the International Neuropsychological Society*, *7*, 574–585.

Dobbs, B. M., Dobbs, A. R., & Kiss, I. (2001). Working memory deficits associated with chronic fatigue syndrome. *Journal of the International Neuropsychological Society*, *7*, 285–293.

Groeger, J. A., Field, D., & Hammond, S. A. (1999). Measuring memory span. *International Journal of Psychology*, *34*, 359–363.

Harris, M. (1983). *Culture, people, nature: An introduction to general anthropology* (3rd ed.). New York: Harper & Row.

Hester, R. L., Kinsella, G. J., & Ong, B. (2004). Effect of age on forward and backward span tasks. *Journal of the International Neuropsychological Society*, *10*, 475–481.

Lezak, M. (1995). *Neuropsychological assessement* (3rd ed.). New York: Oxford University Press.

Myerson, J., Emery, L., White, D. A., & Hale, S. (2003). Effects of age, domain, and processing demands on memory span: Evidence for differential decline. *Aging Neuropsychology and Cognition*, *10*, 20–27.

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

Nell, V. (2000). *Cross-cultural neuropsychological assessment. Theory and practice*. Mahwah, NJ: Lawrence Erlbaum Associates, Inc.

Ostrosky-Solís, F., Ardila, A., & Roselli, M. (1999). NEUROPSI: A brief neuropsychological test battery in Spanish with norms by age and educational level. *Journal of the International Neuropsychological Society*, *5*, 413–433.

Ostrosky-Solís, F., Ardila, A., Roselli, M., Lopez-Arango, G., & Uriel-Mendoza, V. (1998). Neuropsychological test performance in illiterates. *Archives of Clinical Neuropsychology*, *13*, 645–660.

Ostrosky-Solís, F., Gómez, M. E., Matute, E., Rosselli, M., Ardila, A., & Pineda, D. (2003). *NEUROPSI Atención y Memoria 6 a 85 años [NEUROPSI Attention and Memory 6 to 85 years]*. Mexico: American Book Store.

Petersson, K. M., Reis, A., & Ingvar, M. (2001). Cognitive processing in literate and illiterate subjects: A review of some recent behavioural and functional neuroimaging data. *Scandinavian Journal of Psychology*, *42*, 251–267.

Powell, D. H., & Hiatt, M. D. (1996). Auditory and visual recall of forward and backward digit spans. *Perceptual and Motor Skills*, *82*, 1099–1103.

Reis, A., & Castro-Caldas, A. (1997). Illiteracy: A bias for cognitive development. *Journal of the International Neuropsychological Society*, *3*, 444–450.

Reis, A., Guerreiro, M., García, C., & Castro-Caldas, A. (1995). How does an illiterate subject process the lexical component of arithmetics. *Journal of the International Neuropsychological Society*, *1*, 206.

Reynolds, C. R., Willson, V. L., & Ramsey, M. (1999). Intellectual differences among Mexican Americans, Papagos and Whites, independent of g. *Personality and Individual Differences*, *27*, 1181–1187.

Rosselli, M., & Ardila, A. (2003). The impact of culture and education on non-verbal neuropsychological measurements: A critical review. *Brain and Cognition*, *52*, 326–333.

Rosselli, M., Ardila, A., & Rosas, P. (1990). Neuropsychological assessment in illiterates II: Language and praxic abilities. *Brain and Cognition*, *12*, 281–296.

Salthouse, T. A., Fristoe, N. M., Lineweaver, T. T., & Coon, V. E. (1995). Aging of attention: Does the ability to divide decline? *Memory and Cognition*, *23*, 59–71.

Schwarzer, R. (1994). *Meta-analysis programs* (Version 5.3.1) [Computer software]. Berlin: Author.

Shweder, R. A. (1999). Why cultural psychology? *Ethos*, *27*, 62–73.

Wilde, N., & Strauss, E. (2002). Functional equivalence of WAIS-III/WSM-III digit and spatial span under forward and backward recall conditions. *The Clinical Neuropsychologist*, *16*, 322–330.

Wilde, N. J., Strauss, E., & Tulsky, D. S. (2004). Memory span on the Wechsler scale. *Journal of Clinical and Experimental Neuropsychology*, *26*, 539–549.