Comparative study of visual and verbal short-term memory in English and Spanish speakers:
Testing a linguistic hypothesis

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Abstract
It has been proposed that differences in digit span performance between English and Spanish speakers are
due to the greater number of syllables per digit in the Spanish language. To test this hypothesis, we studied
the performance of 30 English- and 30 Spanish-speaking elders on the Wechsler Adult Intelligence Scale-
Revised (WAIS-R) Digit Span Subtest, a modified digit span test that was linguistically comparable for both
languages, and the Corsi Block Test. Consistent with previous reports, we found that English speakers scored
significantly higher than Spanish speakers on WAIS-R Digit Span Forward. Group differences were reduced
on the modified Digit Span Forward, but remained significant. English and Spanish speakers scored
comparably on Digit Span Backward (WAIS-R and modified) and Visual Span. We suggest that although
differences in the number of syllables per digit string are in part responsible for the lower performance of
Spanish speakers on Digit Span Forward, cultural and educational issues also contribute to the observed
differences between English and Spanish speakers. (JINS, 1996, 2, 105-110.)

Keywords: Cross-cultural, Spanish, Short-term memory, Digit Span

INTRODUCTION
Since the late 1960s, due in part to the growing popula-
tion of linguistically diverse people in the United States,
many studies have compared neuropsychological test per-
formance between Anglo Americans and Hispanic Amer-
icans. Performance differences have consistently been
found in the Digit Span Test (López & Taussig, 1991;
Loewenstein et al., 1993; Naveh-Benjamin & Ayres, 1986).

These differences, which are in favor of English speak-
ners, have been explained on a linguistic basis by consid-
ering working memory as a phonemically based store of
limited temporal capacity (Baddeley et al., 1975; Naveh-
Benjamin & Ayres, 1986). It has been shown that subjects
speaking languages in which the length of the words that
express the numbers (i.e., the number's phonetic code) is
shorter (either in terms of number of syllables, length of
the syllables, or both) are able to repeat more digits than
subjects speaking in languages with long phonetic codes
(Ellis & Hennelly, 1980; Hoosain, 1982; Naveh-Benjamin
matched groups of English- and Spanish-speaking pa-
tients diagnosed with Alzheimer's disease as well as non-
impaired elderly. They found a higher WAIS-R Digit
Span score in the English-speaking groups. More recently,
using a sample of Alzheimer's disease patients, Loewen-
stein et al. (1993) found that the differences in WAIS-R
Digit Span between Spanish and English speakers per-
sisted even after statistically controlling for the number
of syllables per digit. However, no study to date has di-
rectly tested the hypothesis that the differences in num-
ber of syllables are responsible for different digit span
performance in Spanish- and English-speaking elderly.
Additionally, only one study (Loewenstein et al., 1993)
has analyzed performance of English and Spanish speak-
ers on Digit Span Forward and Digit Span Backward sep-

dately. Finally, no previous study has compared the
performance of English and Spanish speakers on Visual
Span, which entirely eliminates linguistic differences.

We designed a new digit span test that equated the En-

glish and Spanish versions for total number of syllables.
We also introduced a visual span test to compare the performance of English and Spanish speakers on nonverbal span.

METHODS

Subjects

Sixty subjects (30 English and 30 Spanish speakers) were recruited from current participants in the Washington Heights–Inwood Columbia Aging Project, a community-based epidemiological study of aging and dementia in Northern Manhattan, NY. All subjects had completed a comprehensive neurological and neuropsychological evaluation (Stern et al., 1992). Only subjects who had been diagnosed as not demented at a consensus conference of neurologists and neuropsychologists were recruited for the current study. To maximize the comparability of our English and Spanish groups in terms of social and educational variables, subject sampling was restricted to Hispanics and Black Americans.

All of the subjects in the Spanish-speaking group were U.S. immigrants who identified themselves as Hispanic and spoke predominantly or exclusively Spanish. Spanish-speaking subjects were primarily from the Dominican Republic (43%), Cuba (33%), and Puerto Rico (13%). Additionally, there was one subject from Columbia, one from Ecuador, and one from Honduras. The mean age at the time of immigration was 44.33 yr (SD = 15.12 yr), and the mean duration of residence in the United States was 30.63 yr (SD = 13.37 yr). When asked how well they spoke English, 33% of Spanish speakers responded “not at all,” 47% “not well,” 13% “well,” and 7% “very well.” All of the subjects in the Spanish-speaking group reported Spanish as the predominant language spoken at home.

Twenty-nine of the 30 English-speaking subjects were born and raised in the United States. Most of the English-speaking subjects were self-described as Black American (40%) or African-American (33%). The remaining English speakers identified themselves as American (20%), Jamaican American (3%), and Black (3%).

Demographic characteristics of the subject groups are presented in Table 1. Spanish and English speakers were comparable in terms of age, distribution of sex, and occupational attainment. The group of English speakers, however, had significantly more years of education than the Spanish-speaking group (t = 2.13, p < 0.05).

Materials

Digit Span

The Wechsler Adult Intelligence Scale–Revised (WAIS-R; Wechsler, 1981) Digit Span Subtest was chosen because of its extended use and available standardized scoring norms. The WAIS-R instructions were translated into Spanish and used for both groups. The same series of digits (ranging from one to nine) was used for both groups. Because six of the nine digits used in the Digit Span test have two syllables in Spanish, while only one of the digits has two syllables in English, the two tasks differed in terms of average number of syllables per digit string (mean number of syllables per digit was 1.67 for the Spanish version and 1.12 for the English version).

Modified Digit Span

A new digit span test was designed to reduce the differences in number of syllables between the Spanish and English digit spans. Some of the two-syllable digits in the Spanish language (1, 4, 5, 9) were eliminated in both the

<table>
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<th>Table 1. Demographic characteristics of the English and Spanish speakers</th>
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<tr>
<td><strong>English speakers</strong></td>
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<tr>
<td>(n = 30)</td>
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<tr>
<td>Mean (SD) age</td>
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<td>Sex (% female)</td>
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<td>Mean (SD) years</td>
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*a n = 25 Spanish speakers on Visual Span. This measure was added to the paradigm after testing was completed on five Spanish-speaking subjects. Demographic characteristics of the 25 Spanish speakers were comparable to those described above.

*b p values were obtained from chi-square and t-tests used to assess group differences.
Spanish and English version of the new test and were replaced by other numbers with the same number of syllables in both Spanish and English (10, 15, 20). Thus, the numbers 2, 3, 6, 7, 8, 10, 15, and 20 were used in both language versions, resulting in a more comparable mean length of syllables per number (1.38 in English and 1.5 in Spanish). To equate the Spanish and English versions we took the following steps: (1) We maintained an exact equivalence in the number of syllables across the corresponding strings of each test version. (2) Long and short digits were alternated in the same order across the Spanish and English versions. (3) When a digit was repeated within a string, the positions of the repeated digit were the same in both languages. (4) The same number of two-digit numbers was included within every string of digits for each version. (5) Because some numbers have a different number of syllables in English than in Spanish, the strings that were equivalent in length did not necessarily have exactly the same numbers. (6) To avoid the possible effect of phonemic similarity on the short-term memory span (Baddeley et al., 1975), we gave priority to phonemic variety rather than to systematic or random sequences of digits. Specifically, pairs of numbers in which the last phoneme of the first pair was equal to the first phoneme of the second pair were avoided (e.g., "six-seven" in the English version or "dos-seis" in the Spanish version). The result was an English and Spanish version of a Digit Span Test that was comparable in terms of number of syllables in every string, string rhythm, and relative position of the two-digit numbers within the string, although the same digits were not necessarily used for the equivalent series in the English and Spanish forms.

Corsi Block Test

An adapted version of the Corsi Block Test (Milner, 1971) was used for both the Spanish- and English-speaking subjects. It consisted of nine black cubes randomly fastened to a black cardboard as described by Milner (1971). The examiner touched a series of blocks, one at a time, and then the subject was instructed to point to the same series of blocks. For the backward tapping span task, subjects were instructed to touch the same blocks in the reverse order of the examiner. Each block was identified by a number, facing the examiner. The series of numbers for both the English- and the Spanish-speaking group was the same as that used in the WAIS-R Digit Span Test. The task was terminated after two failures of the same span length.

Procedure

All tests were administered by the same examiner (J.O.) as part of a comprehensive neuropsychological test battery. The order of administration of the modified and standard digit span tests was counterbalanced across the subjects. For all the subjects, the Corsi Block Test was performed at the end of the session. The instructions and strings of digits on the two digit span versions were administered via tape recorder. The voice on the tape recorder was that of an experienced bilingual tester in our research group. The Corsi Block Test was administered at the approximate speed of one block per second. Each test was discontinued when the subject was not able to repeat either of the two series of digits of the same difficulty level. The backward part of every test was always administered immediately following the forward section. For every task, we recorded the longest string of digits or blocks responded to correctly, as well as the total number of correctly repeated strings.

RESULTS

Performances of English and Spanish speakers on Digit Span Forward (WAIS-R and modified), Digit Span Backward (WAIS-R and modified), and Visual Span Forward and Visual Span Backward were relatively comparable when considering either the longest string of digits/taps repeated correctly or the total number of strings correctly repeated. Results presented here correspond to the analyses of the total number of strings correctly repeated. All analyses statistically controlled for group differences in education.

We first determined whether the order of task administration (i.e., standard vs. modified digit span first) affected test performance. Analyses of variance confirmed that there was no significant effect of order of task administration on any of the digit span measures, nor were there any significant order by language interactions.

Digit Span Forward

A group (English vs. Spanish) by condition (standard vs. modified digits) repeated measures analysis of covariance on Digit Span Forward yielded significant main effects for group ($F = 25.70, p < .0001$) and condition ($F = 18.23, p < .0001$). The group by condition interaction approached significance ($F = 3.28, p = .07$). Spanish speakers had shorter digit spans than English speakers, and both groups had shorter digit spans on the modified task than on the standard digit span (see Fig. 1).

Digit Span Backward

Analysis of covariance on Digit Span Backward yielded a main effect of condition that approached significance ($F = 3.85, p = .052$), but not a significant group effect ($F = 1.85, p = .18$) or group by condition interaction ($F = 1.33, p = .25$). Both Spanish and English speakers had shorter digit spans on the modified Digit Span Backward than on the WAIS-R version (see Fig. 2).
Visual Span

Performances on Visual Span Forward and Visual Span Backward were comparable for English and Spanish speakers (see Fig. 3).

DISCUSSION

To test the hypothesis that different numbers of syllables determine the difference in performance on the WAIS-R Digit Span subscale between the English and Spanish speakers, we administered the WAIS-R Digit Span subscale, a modified digit span test with linguistically comparable series of digits, and a visual span test to Spanish- and English-speaking adults. Spanish speakers had significantly shorter digit spans when compared to the English speakers on both the standard and modified forward digit span test. Spanish and English speakers did not significantly differ, however, on either Digit Span Backward or Visual Span. These results differ in part from those of Loewenstein et al. (1993), who showed significant differences between English- and Spanish-speaking Alzheimer's disease patients on both forward and backward WAIS-R Digit Span subscales, even after statistically controlling for number of syllables per digit. Our English speakers showed a large decrease in performance on the modified versions of both the forward and backward digit span tests as compared to the WAIS-R versions, whereas for the Spanish speakers the condition effect was either moderate (Digit Span Forward) or very mild (Digit Span Backward) (see Figs. 1 and 2). On the Visual Span Test, which eliminates any verbal component in the assessment of short-term memory, group scores were similar (see Fig. 3). These results suggest that differences in the number of syllables per digit string are in part responsible for the lower performance of Spanish speakers relative to English speakers on the WAIS-R Digit Span subscale.

We found a condition effect for both Digit Span Forward and Digit Span Backward: Both groups scored lower on the modified digit spans than on the standard (WAIS-R) versions (see Figs. 1 and 2). In terms of the linguistic hypothesis, this effect was in the predicted direction for the English-speaking group. Spanish speakers, however, scored contrary to what we would have expected. To rule out a possible educational effect responsible for these results, we re-ran the analyses after equating the two groups in terms of education by excluding the lowest educated Hispanics and the highest educated English speakers. Our results, both in the forward and backward digit span tests, remained the same.

Another possible explanation for these results is that the inclusion of two-digit numbers in the modified version interfered with the use of chunking as strategy. Chunking, which consists of recoding simple auditory-verbal stimuli into higher-order units, is commonly invoked as a strategy to memorize digits by both English (McCarthy & Warrington, 1990) and Spanish speakers (Loewenstein et al., 1994). On the modified digit span
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test, in addition to remembering the digits, subjects had
to remember whether numbers had single or double dig-
tests. It is possible, therefore, that the random alternation of one- and two-digit numbers in the modified digit span
test produced a less favorable situation for subjects to use
a chunking strategy. The fact that English speakers de-
creased more than Spanish speakers on the modified digit
spans relative to the WAIS-R versions may be due to the
combined effects of the greater linguistic burden associ-
ated with the increase in average number of syllables per
digit and difficulty using chunking as a rehearsal strategy.

Whereas a less favorable chunking situation seems a
plausible explanation for the observed condition effect,
we do not think that it fully accounts for all of our find-
ings, particularly in Digit Span Forward. Our modified
digit span test had not only the same number of syllables
for each language group, but also the same amount of
two-digit numbers in exactly the same position of the
string. It is possible that other cultural issues that we did
not control for influenced performances. We do not think
that differences in socioeconomic status can be responsi-
able, as our two samples were comparable in terms of oc-
cupational history and area of living (Hollingshead &
Redlich, 1958). Differences in level of education can be
ruled out since we statistically controlled for years of ed-
cuation and, additionally, obtained the same results after
repeating our analysis with a reduced, education-matched
group of subjects. We cannot exclude the possibility, how-
ever, that differences in quality rather than quantity of
education between the English- and Spanish-speaking
countries are responsible for the observed group effect in
the Digit Span Forward tests. All of our Spanish-speaking
subjects were older adults who came to the United States
after having been born, raised, and educated in their orig-
inal Hispanic countries. In contrast, all but one of our
English-speaking subjects were born and raised in the
United States. Cultural differences in education may have
contributed to the observed differences. A way of further
testing this hypothesis would be to compare short-term
verbal memory for digits between poorly and highly ac-
culturated Hispanics.

An alternative explanation for the poorer performance
of our Spanish-speaking subjects on the digit span mea-
sures is that some knowledge of English as a second lan-
guage interfered with test performance in their primary
language. Although all subjects in the Spanish-speaking
group identified Spanish as their predominant language,
most were able to speak at least a small amount of En-
lish, and 20% of this group spoke English well or very
well. To minimize interference effects between languages,
exclusive Spanish was spoken during the test session,
even with bilingual Hispanics. Nevertheless, the potential
for such interference existed for Spanish-speaking, but
not English-speaking, subjects, and thus may have con-
tributed to the observed results.

Importantly, our subject sample consisted exclusively
of older adults; furthermore, our Spanish-speaking group
was comprised primarily of Caribbean Hispanics who
immigrated to the United States during adulthood. It is
therefore unclear to what extent the results reported here
will generalize to younger cohorts, other Hispanic popu-
lations, or subjects who immigrated earlier in life. The
fact that previous investigators have observed similar re-
results in various cohorts, however, suggests that our find-
ings are relatively robust.

In summary, we compared performance on one non-
verbal and two verbal short-term memory tests in an at-
tempts to explore the nature of the commonly observed
differences in digit span between English and Spanish
speakers. Results from our modified digit span test sug-
that group differences are in fact influenced by the
length of the digits. However, our modified test failed to
completely eliminate the differences between English and
Spanish speakers in the Digit Span Forward. Our results
on Visual Span indicate that differences in Digit Span be-
tween English and Spanish speakers are specifically verbal.
We suggest that qualitative educational and cultural fac-
tors may contribute to the remaining group differences.

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