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One-trial 10-item free-recall performance in Taiwanese elderly and near-elderly: A potential screen for cognitive decline

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Abstract

To explore a one-trial 10-item free-recall test as a potential dementia screening tool, we analyzed recall scores and individualized serial position effects in near-elderly ($N = 2,336$) and elderly ($N = 2,371$) participants in a population-based survey in Taiwan. Age and sex were significantly associated with recall score [younger > older ($p < 0.001$); men > women ($p < 0.001$)]; after controlling for gender and age group, weak association between recall and education was still observed. By contrast, serial position effects (SPEs), defined for each participant and analyzed aggregated over each age group, were not associated with education and tended not to be associated with sex. Primacy effects were observed in 67 to 80 percent, and recency effects were observed in 41 to 54 percent of respondents. Because SPEs were defined for each respondent, we could determine that loss of the primacy effect was associated with significantly larger losses in total recall score in elderly persons who had exhibited both SPEs at the first survey, as compared to those who maintained both SPEs at successive surveys ($p < 0.01$). Elderly subjects showed slight longitudinal decline in free recall. A one-trial 10-item free-recall test demonstrated age-related cognitive decline in this Taiwanese population survey cohort; SPEs at the individual level may be useful markers for important cognitive change and warrant further study and benchmarking against valid and reliable tests of memory and cognitive decline.

Keywords

serial position effects; cognitive decline; primacy effect; dementia; education

Introduction

Identifying potential cases of dementia as early as possible is a public health imperative.¹ As such, large ongoing public health projects that do not have dementia or cognitive impairment as their central focus [e.g., the Longitudinal Study on Aging (LSOA) in the United States] could nonetheless provide additional screening opportunities. Less-severe cognitive impairments are the most difficult to identify in the clinical setting,² however, and so could be underdetected in the larger-scale setting or in contexts where cognitive

impairment is not the primary focus. A short and simple screening instrument is needed, and cross-cultural usability would increase utility and acceptability. Toward this end, this paper describes a one-trial 10-item free-recall test that was incorporated into a large nonwestern cohort survey. We examine a recall score (number correct) as well as the presence of serial position effects (SPEs) at the individual level based on this task.

Free recall

During a free-recall task, a list of words is given and recall can be in any order. When subjects' free-recall performance is better for the initial and final items in the stimulus list, these effects are known as "primacy" and "recency," respectively. Primacy effects are believed to occur mainly because those items have had the greatest degree of rehearsal, whereas recency effects are believed to occur because the last items on the list are still active in immediate or short-term memory.³ When the proportion of a group with a correct response is plotted against serial position of the items in the given list, a U-shape is typically observed, reflecting better performance for items early and late in the list, relative to that for items in the middle of the list. This pattern, referred to as the serial position curve, is characteristic of normal free-recall performance⁴ and is defined at the group level.

SPEs, well established since the 1950s,⁴ still currently produce interesting research results. In a recent example, Bayley et al.⁵ explored free-recall performance ("score") and SPEs at the group level in persons with mild Alzheimer's disease, individuals with amnesia (due to electroconvulsive therapy, i.e., not dementia), and normal controls. They found that both of the impaired groups exhibited reduced recall (i.e., fewer words recalled) relative to the normal controls; the group with mild Alzheimer's disease demonstrated reduced primacy effects, but intact recency effects, while the amnesic and normal groups exhibited intact primacy and recency effects. This suggests that the presence of primacy effects plus the recall performance from a free-recall task might be useful in identifying individuals at risk of, or having, memory impairment (reduced recall) or dementia (reduced primacy effect) of any etiology.

Free-recall performance can reflect decline due to aging⁶ and has been found to predict dementia within five years.⁷ These recent investigations notwithstanding, the effects of aging on SPEs have not been explored longitudinally; nor have they been quantified at the individual, rather than the group, level.

We report here the performance on a one-trial, 10-item free-recall test in terms of number correct (out of 10), plus primacy and recency effects at the individual level, in two community-based cohorts in Taiwan. The relationships between education and both recall and SPEs were explored, and we also examined changes in recall over a three-year period (1996 to 1999) to assess SPEs at the individual level longitudinally.

Methods

Subjects

The Survey of Health and Living Status of the Elderly in Taiwan has been collecting data from a large, nationally representative cohort since 1989.⁸ The original purpose of this survey was to longitudinally collect comprehensive data on the social, economic, physical, and emotional status of the elderly in Taiwan. Like other longitudinal studies of aging (e.g., LSOA, National Center for Health Statistics), the cognitive dimension of aging was not an area of primary interest in the Taiwanese survey when it began, and cognitive measures were included for descriptive, not diagnostic, purposes.

The selection of these respondents is fully described elsewhere.⁸ In brief, 4,412 individuals were included in the original sample of all persons in the household register of Taiwan (exclusive of aboriginal areas) who were at least 60 years old at the end of 1988. Individuals in the sample who were residing in hospitals or institutions were included in this sampling plan. The response rate in 1989 was 91.8 percent (N = 4,049). In 1996, two changes were made to the ongoing survey. First, a cohort of near-elderly individuals, aged 50 to 66 years in 1996, was added. Second, a set of questions pertaining to cognitive function (added in 1993) was expanded to include a one-trial, 10-item free-recall task.

Respondents during the 1996 wave of the Survey of Health and Living Status of the Elderly in Taiwan, who were aged 67 years or older, were individuals from the original 1989 wave of the survey who were not lost to follow-up, deceased, or unable to be tested directly owing to deafness, dementia, or other conditions. Of the original elderly sample, 2,669 (65.9 percent) responded during the 1996 wave (an 89 percent response rate for the remainder of the original cohort⁹); although 2,336 (88.8 percent) of these had valid free-recall scores (i.e., scores of 0 to 10), the item-level responses were recorded for only 1,183 (49.9 percent) with all 10 responses at the 1996 visit.

For the 1996 wave of the survey, the near-elderly cohort was selected under a sampling plan similar to that used in 1989. The near-elderly cohort was administered a Survey of the Health and Living Status of the Middle Aged in Taiwan. This questionnaire was similar in content, but not identical, to the survey of the elderly¹⁰; both cohorts were administered the same one-trial, 10-item free-recall test. Similar to the elderly cohort, although 2,336 of the 2,462 (94.9 percent) of the near-elderly cohort had free-recall scores recorded (i.e., 0 to 10), 913 (39.1 percent) had recorded item-level responses to the free-recall test in 1996. Issues surrounding the differences between respondents with and without item-level data are presented with the Results.

Free-recall test

The free-recall test was a single 10-item list of words created in Chinese for the 1996 wave of the survey (Appendix). The same list was readministered in 1999. Respondents heard the list of 10 words (train, dog, ship, watermelon, stone, soda pop, cloth, springtime, tree, roof) one time and were asked to repeat it immediately. Each correctly recalled item scored 1 point, and totals were recorded when the survey was administered; item-level data was entered from the survey forms specifically for these analyses in 2002.

Statistical methods

The analyses involved two steps: First, the number of words (of 10) correctly recalled at each visit and change in recall scores from 1996 to 1999 were examined in terms of associations with gender, age, and education. The second analytic step was to examine primacy and recency effects and their associations with the same three variables. All analyses were carried out using SPSS version 11.5 for Windows (SPSS Inc., Chicago, IL).

Results

Primacy and recency

To identify the primacy and recency portions of the curve, correct responses for each item in the list at the 1996 visit were plotted. Figure 1 presents the distribution of correct responses across the 10-item list at the 1996 visit. The primacy and recency sections of the list were defined based on the plots in Figure 1A and are shown for the 1996 data in Figure 1B.

Typically, the first and last three or four items (depending on list length) are taken to represent the primacy and recency regions of the list, respectively (although see reference 4). Figure 1A shows that, for the elderly and near-elderly, recall of the first and last two list items represents the best performance. This pattern was observed at both visits (data not shown). Based on this observation, for each participant, we calculated mean correct from the primacy (items 1 and 2), middle (items 3 to 8), and recency (items 9 and 10) regions of the list (see Figure 1B for 1996 data). It should be noted that, unlike the clear U-shaped curve that is typically described and discussed (Figure 1B), the correct response rate over this 10-item list is not a smooth curve (Figure 1A); instead, our curves are very similar in shape (middle-item “bump-ups” included) to those presented by Bayley et al.⁵

Differences between the means for primacy and middle regions and recency and middle regions indicated whether an individual exhibited primacy and/or recency effects. For an individual to have evidence of SPEs, however, the total free-recall score had to be between 2 and 9 (inclusive). In respondents with recall at a given visit ranging from 2 to 9, if an individual's mean performance on the primacy region of the list (i.e., items 1 and 2) was greater than their mean performance on the middle region (i.e., items 3 to 8), the individual was characterized as exhibiting a primacy effect at that visit. Mean recency (i.e., items 9 and 10) performance greater than mean middle performance was likewise indicative of a recency effect. An ordinal variable for each visit was created to represent the SPEs for each subject. Best (i.e., most “normal”) performance was the presence of both primacy and recency effects; next-best performance was the presence of only the primacy effect,^{5,11} followed by the presence of only the recency effect, and the worst performance was the absence of both effects. People with neither SPE tended to have very low, rather than uniformly high, scores (data not shown).

Background variables

Table 1 presents the descriptive statistics for background variables in the near-elderly (N = 2,336) and elderly (N = 2,371) cohorts, including their ages in 1996. The near-elderly cohort was 48.5 percent female; the elderly cohort was 43.9 percent female. The younger

respondents had significantly more education on average (near-elderly, 5.3 ± 4.4 years; elderly, 4.2 ± 4.6 years, $z = -10.9$, $p < 0.001$).

As noted previously, only a subset of each cohort had item-level data for the free-recall test in 1996. Individuals in the elderly cohort with scores but no item-level data were slightly, but significantly, younger [mean (SD), 73.3 (4.9)] than elderly respondents with both scores and item-level data [mean (SD), 74.2 (5.9); $z = -2.8$, $p < 0.01$]; they also had slightly, but significantly, higher free-recall performance [mean (SD), 3.9 (2.0)] than respondents with both scores and item-level data [mean (SD), 3.5 (2.7); $z = -4.8$, $p < 0.001$]. The differences in the near-elderly group were not significant (all $p > 0.07$). Men and women in both age groups were equally likely to have scores recorded in 1996 but not items (both chi square < 1.3 ; both $p > 0.13$). After the first survey, the vast majority of respondents (nearly 90 percent) had total scores and item-level data for this task, suggesting that the absence of item-level information from 1996 owed to recording, and not to subject, effects.

Free recall

On average, respondents recalled less than one-half of the 10 items in the free-recall test at each survey wave. The free-recall performance (mean $\pm$ standard deviation) of the elderly cohort was significantly worse than that of the near-elderly in 1996 (near-elderly, 4.7 ± 2.3 ; elderly, 3.7 ± 2.4 ; $p < 0.001$) and 1999 (near-elderly, 4.7 ± 2.3 ; elderly, 3.5 ± 2.3 ; $p < 0.001$). Recall was better for men than for women in both cohorts at both visits (near-elderly, 1996: $z = -6.5$, $p < 0.001$; 1999: $z = -5.7$, $p < 0.001$; elderly, 1996: $z = -8.1$, $p < 0.001$; 1999: $z = -6.8$, $p < 0.001$) (Table 1).

Between the triennial surveys (1996 to 1999), the elderly lost significantly more than the near-elderly in free-recall performance (-0.30 ± 2.8 and 0.04 ± 2.7 , respectively; $p < 0.001$), although change averaged less than one-half of an item. Women lost more than men in both groups, although not significantly, in terms of free-recall performance between 1996 and 1999 (both $p > 0.50$).

Age and education

Correlation coefficients were calculated to estimate the association between age and education and free-recall performance and changes in these values. Gender was partialled out of these correlational analyses because of its association with age (women older, Table 1), recall performance (women worse, see previous), and the large disparities between educational attainment of men and women in this survey.⁹ The two age cohorts were analyzed separately.

After controlling for gender, age was negatively associated with free recall at each wave for both cohorts (ranges of all correlations: near-elderly, -0.16 to -0.20 ; elderly, -0.20 to -0.25 ; all $p < 0.001$), accounting for 3 to 4 percent of the variance in recall in 1996 (near-elderly, 2.6 percent; elderly, 3.9 percent) and 1999 (near-elderly, 3.9 percent; elderly, 4.3 percent). Age at the first test did not account for more than 0.1 percent of variance in change in free-recall performance from 1996 to 1999 (near-elderly, $p > 0.05$; elderly, $p > 0.3$).

After controlling for gender, higher education was associated with better recall at each wave for both cohorts (all $p < 0.001$). Education accounted for close to 5 percent of the variance in recall in 1996 (near-elderly, 3.7 percent; elderly, 6.4 percent) and 1999 (near-elderly, 6.2 percent; elderly, 4.7 percent). In both cohorts, education was not associated with change in free recall between 1996 and 1999 $r =$ (near-elderly, 0.04; elderly, $r = -0.02$; both $p > 0.1$).

Serial position effects

Presence of SPEs for men and women in each age group by survey wave is presented in Table 2. The distributions of SPEs (both, primacy, recency, neither) were significantly different for the near-elderly and elderly cohorts in 1996 (60.1, $p < 0.001$) and 1999 (24.8, $p < 0.001$).

Kendall's tau-b was calculated to examine the association between education (recoded as an ordinal categorical variable, 0 to four years, five to 10 years, and 11+ years of education) and the ordinal SPE variable calculated for each subject with free-recall total between 2 and 9 (see Statistical Methods). These cross-tabulations were computed for each cohort, and separately for men and women in each age cohort who had item-level responses for a given survey wave (Table 2).

There was no significant association between SPEs and education level in either cohort for men or women when analyzed separately (near-elderly, all $p > 0.55$; elderly, all $p > 0.14$), nor was association significant when collapsed across gender in each cohort. It was noted that more of the individuals with more education tended to exhibit both primacy and recency for both men and women in both age groups and at every survey; these differences failed to reach significance, however. Given the similarity of findings for men and women, the proportions in Table 2 represent male and female respondents together.

Figures 2A and 2B present the SPEs separated by education (broken down into three levels: 0 to four, five to 10, and 11+ years) for men and women separately (collapsed over age group) at the first visit (1996).

It can be seen that, although more education is associated with greater recall at every list position, recency effects are very small on average for each educational grouping. Among individuals with free-recall scores between 2 and 9, between 6.3 and 10.3 percent of respondents exhibited neither effect across waves.

In the near-elderly cohort, more men than women exhibited both primacy and recency effects in 1996 and 1999, but these differences did not reach significance (all $p > 0.15$). In the elderly cohort, more men than women showed both primacy and recency effects in both surveys.

To explore SPEs at the individual level, we identified those persons in each cohort for whom both primacy and recency effects were present at the 1996 survey. Of these, we identified those who still had both effects in 1999 and compared them to those who had lost the primacy effect, which Bayley et al had found to be a distinguishing feature of persons with Alzheimer's disease compared to those with amnesia. In the near-elderly cohort, 10 of the 141 individuals with both SPEs in 1996 had lost the primacy effect by 1999; change in recall

score was not significantly different in these two groups (both lost less than one-half of a point on average). In the elderly cohort, however, 18 of the 105 individuals with both SPEs in 1996 had lost the primacy effect by 1999, and these individuals had lost significantly more (-1.28 ± 1.2) than those who still had both in 1999 (-0.17 ± 2.0 , $p < 0.05$).

Discussion

In terms of mean score, the one-trial 10-item free-recall test distinguished between elderly (aged 67 + years) and near-elderly (aged 50 to 66 years) in community samples from Taiwan. Overall, we found that education did not contribute much to free-recall performance in later life beyond what age and gender provide in terms of explanatory power for this cohort. The present results suggest that the one-trial 10-item free-recall test is sensitive to age-related changes cross-sectionally.

Our results suggest that SPEs were significantly different across age cohorts in 1996 and 1999. These results must be considered in the proper context of these post hoc analyses: the data were not collected for the purpose of establishing this effect, and missing data at the item level may have introduced uncontrolled biases. Our assessment of the potential impact of missing item-level data on our conclusions suggests that the process was random. We observed the typical SPEs overall, which supports the interpretability of our results; however, the primacy effects were more pronounced than recency for both cohorts at both waves. Whether alone or with the other effect, primacy effects were observed in 67 to 80 percent of respondents in both cohorts at each visit, while recency effects were only observed in 41 to 54 percent of each cohort at any visit. No evidence of an association between education and SPEs was found. Because many tests of cognitive function (e.g., the Mini-Mental Status Examination¹²) are sensitive to education, SPEs at the individual level may be useful in settings in which educational attainment may vary widely. Because this is the first report to describe individual-level SPEs in a large sample, future studies should be implemented to replicate our results and particularly to examine the association of individual-level SPEs and reliable and valid tests of memory and cognitive function.

Influence of education on detection of effects

The generalizability of our results regarding education and SPEs may be affected by the difficulty of modeling the influence of education on recall or the detection of SPEs. SPEs are not interpretable when total free-recall scores are 0, 1, or 10, affecting 7 to 11 percent of near-elderly men and 10 to 12 percent of near-elderly women, and nearly twice as many elderly men (14 to 18 percent) and elderly women (24 to 29 percent) at any given visit in this sample. Analytic techniques that control for individual variation (i.e., random- or mixed-effect models) might facilitate our future studies.

This is the first study, to our knowledge, in which SPEs were identified at the individual level. This fact may account for some differences between our findings and those of other groups (e.g., references 5, 13, 14), namely, that most individuals (50 to 60 percent) were missing a recency effect. This was not an artifact of evaluating SPEs at the individual level, however; Figures 1A and 1B show that, at the group level, a primacy effect was more prominent in each age group than a recency effect. It is unclear how the majority of a

community sample can be missing the recency effect altogether, yet this was observed in both age cohorts. Because the cognitive status of the subjects (i.e., whether any person was cognitively intact or impaired) was unknown, cognitive status may also have contributed to the unexpectedly low rate of recency effects in these individuals. It is important to note that the plot of percent of group recalling items relative to their serial positions in the list (Figure 1A) very closely matches the plot presented by Bayley et al.,⁵ although our cohorts were 50 to 100 times larger than those groups.

Recall for two items in the middle of the list (items 4 and 5) was better than that for the last two items for the near-elderly and elderly at each visit (Figure 1A; this pattern was replicated at every visit in both age groups; data not shown). The analyses of SPEs were rerun after primacy and recency were recalculated excluding items 4 and 5, and the results were identical with a single exception: For the 1996 wave, SPEs were significantly associated with gender in the elderly cohort, whereas SPEs calculated using all 10 items (i.e., including items 4 and 5) were not significantly different for men and women in the elderly cohort. It is unclear how the items in this task affected the appearance of individual-level SPEs in this cohort. Other authors^{15,16} have also not addressed similar performance characteristics; the simplification of actual recall performance to the U shape is based on the presence of recency and primacy effects at the group level. This generally supports our individual-level SPE definition, but our main conclusion is that a one-trial/O-item free-recall test could be an important adjunct in large-sample screening efforts. To determine if this is true, individual-level SPEs should be explored further and benchmarked longitudinally with valid and reliable memory and cognition measures.

Implications for screening

It is important to note that the dementia diagnosis is based on functional decline rather than on memory performance (see reference 17 for a review of cognitive screening in clinical settings). In terms of identifying individuals who are likely to meet diagnostic criteria for dementia, however, memory tests continue to be used in screening and in large-scale nonclinical studies such as the Taiwan Survey and the Longitudinal Survey of the LSOA. Using individually defined SPEs, one might be able to detect, for example, the “loss” of the primacy effect in an individual over the course of a large-scale study; this might represent an important change in cognition for that individual and, as our results suggest, would not be sensitive to their education or gender. If a free-recall task is already incorporated into a study, no additional data need be collected; the individual-level identification can proceed on the basis of existing data. If such a task must be integrated into ongoing data collection efforts, its inclusion would be very simple (Appendix) and would add only a few minutes to the data collection. Should this prove to be a valid and reliable marker for important cognitive changes, it would be worth while to include in large-scale studies, even if cognitive changes are not the primary goal. The identification of SPEs at the individual level may be a useful marker of cognitive function, and more in-depth study of their particular properties and applicability is warranted.

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The roles of the authors are as follows: RET, formulating research question, analyzing the data, writing the article; PSA, formulating research question, writing the article; Y-LC, design and implementation of study from which data were derived, writing the article.

Appendix. Free-recall task (Chinese/English translation)

接下來，我要唸出幾項物件，等我唸完後，請你把你記得的部分說一次，但**不一定要照我的順序來說**。

【請先提醒受訪者注意聽，只唸一次，不可重複唸。】

火車、狗、船、西瓜、石頭

汽水、布、春天、樹、屋頂

【在答對的物件上打圈】全部複誦正確的物件數：_____

"Next, I will read out several items. When I have finished, please say all those that you remember, **not necessarily in the order I said them**. [Please remind the respondent that you will read the items only once.]

Train, Dog, Ship, Watermelon, Stone, Soda pop, Cloth, Springtime, Tree, Roof
[Circle the correct items.] Total number of correct items: _____

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Figure 1.

A. Free-recall performance by item list position for near elderly and elderly Taiwanese survey respondents with item-level data in 1996; Figure 1B. Serial position effects data from 1996, listed by age group (elderly and near-elderly).

Figure 2.
Serial position effects in 1996 by education level for men (A) and women (B).

Table 1

Background descriptive data for near elderly and elderly survey respondents with Free-recall scores [mean (SD)]^a

	NE (N = 2,336 in 1996)	NE men (n = 1,202)	NE women (n = 1,134)	E (N = 2,370 in 1996)	E men (n = 1,330)	E women (n = 1,040)
Years of education	5.3 (4.4)	6.7 (4.2)	3.6 (3.7)	4.2 (4.6)	5.8 (4.7)	2.1 (3.4)
Percentage of group with no formal education ^b	28.8	13.2	45.2	46.0	28.1	68.8
Age (yr)	58.0 (4.9)	58.1 (5.0)	57.8 (4.7)	73.3 (5.1)	73.0 (5.0)	73.7 (5.2)
Percent female	48.5	-	-	43.9	-	-
Free-recall score, 1996	4.7 (2.3)	4.9 (2.2)	4.4 (2.3)	3.7 (2.4)	4.0 (2.4)	3.3 (2.3)
Free-recall score, 1999	4.7 (2.3) (n= 1,952)	5.0 (2.3)	4.4 (2.3)	3.5 (2.3) (n= 1,807)	3.8 (2.3)	3.1 (2.3)
1999-1996 (value > 0 = gain)	0.04 (2.7) (n= 1,952)	0.07 (2.7)	-0.002 (2.7)	-0.3 (2.8) (n= 1,807)	-0.29 (2.9)	-0.35 (2.7)

E, elderly; NE, near-elderly

^aDifferences between individuals with and without item-level data were minor (see text), so descriptive statistics for the larger sample (i.e., respondents with and without item-level data) are provided here

^bNo formal education includes individuals reporting 0 years of education (not literate) and those reporting literacy and 0 years of formal education.

Table 2

SPEs (percentage of persons with FR score of 2 to 9 exhibiting each) by age group at each survey wave

Effects	1996		1999	
	NE	E	NE	E
	(n = 722)	(n = 815)	(n = 1,723)	(n = 1,401)
Neither	14.3	17.3	23.1	25.0
Recency	6.2	9.3	6.2	7.5
Primacy	32.5	36.6	31.7	33.7
Both	47.5	36.8	39.0	33.8
Percent female	45.8	41.2	48.6	41.1
Percent of total group with item-level data not eligible for SPEs				
FR				
0 to 1	11.0	25.1	7.9	21.3
10	10.1	6.1	3.7	1.6

E, elderly (aged 67+ years in 1996); FR, free recall; NE, near-elderly (aged 50 to 66 years in 1996); SPEs, serial position effects. All respondents with item-level data and FR score of 2 to 9 for that wave are presented for each wave. Columns do not sum to 100 percent because individuals not eligible for SPE identification are represented as the percentage of all persons per cohort with item-level data, whereas individuals with SPE data represent percents of those SPE-eligible members of the age cohort.