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ORIGINAL ARTICLE

Screening executive function and global cognition with the Nine-Card Sorting Test: healthy participant studies and ageing implications

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Abstract

Background: The Nine-Card Sorting Test provides valid and reliable scores when screening executive function, intelligence, and academic achievement. It is also useful for detecting cognitive impairment and dementia in the elderly and for assessing disease evolution and treatment effectiveness. It deals with three non-verbal sorting principles, individually and in pairs. The presence of risk in the ability to discover and organize visual logical stimuli is explored.
Objectives: This study aimed to describe performance on the Nine-Card Sorting Test in a non-clinical sample, to analyze the effect of demographic variables, and to propose suitable (i.e. the simplest and most homogeneous) cut-off points for possible deficits. Combinations in pairs (double arrays) were assessed (range: 0–3).
Results: Significant effects of age and education were observed, but no interactions among the demographic variables were seen. Differences between the second and third levels of education and between men and women were not significant. The simplest cut-off points were as follows: (i) the median for people younger than 45 years old was 2, independent of educational level; (ii) the median for people older than 74 years old was 1, independent of educational level; and (iii) the median for people aged 45–74 years old was 1 for the first level of education and 2 for higher levels of education.
Conclusion: By considering both the statistical nature of the present dependent variable (number of completed categories) and the clear-cut performance of the different samples studied, this neuropsychological test can be defined as a categorical screening for executive function and global cognition. This is advantageous for reporting risk. Of the whole sample, the 25th percentile (score = 1) represented a valid index for possible deficits. Ageing questions are highlighted. The test is also fruitful for studies on visuospatial organization and its facilitatory and inhibitory mechanisms.

Key words: *cognitive ageing, fluid intelligence, frontal function, neuropsychology, norms, screening mental status.*

INTRODUCTION

The concepts of executive function, frontal function, global cognition, and intelligence are closely related. The study of the interaction (and differences) among such processes, either verbal or non-verbal, has been helpful in understanding complex brain networks and the factors that affect their function.[1–4] When various demographic factors are considered, some functions are more vulnerable than others to the effects of age. Executive and non-verbal functions, including fluid intelligence and visuospatial memory load, are among the most affected by age. Cognitive tasks that involve these functions have proven validity in the early detection of cognitive impairment in the elderly. The ability involved in the performance scale of the Wechsler Adult Intelligence Scale,[5] which tests fluid intelligence,[6] begins to decline among those aged 45–54 years old.[5] Additionally, the brain activation involved in spatial working memory tasks has been shown to radically change at around age 40.[7] In general, attention and memory spans, divided attention, mental tracking, working memory, and processing speed are particularly affected by age; correspondingly, the ability to initiate, organize, maintain, and shift actions and thoughts are also very sensitive to ageing.[8–10] Ageing and cognitive impairment are inversely related to education,[11,12] but gender seems to be more related to the type of task rather than to global cognition.[3,8–10,13–16] However, when the interaction between ageing and cognitive impairment is considered, an increased probability of developing Alzheimer's disease, dementia, and mild cognitive impairment has been observed in women.[17]

The Nine-Card Scoring Test (9CST) encompasses executive function, frontal function, global cognition, and intelligence as well as those that may be affected by ageing earlier.[1,18] The 9CST explores the presence of risk in the ability to discover and organize visual logical stimuli by means of a non-verbal construction task. As this test requires the simultaneous classification of all the cards, the abilities of object assembly, perceptual organization, and spatial working memory are additionally needed.

Previous validity studies have demonstrated that the 9CST significantly discriminates patients with encephalic lesions from healthy participants (HP) and, within such patients, those with anterior (frontal) lesions from those with posterior (temporal, parietal, or occipital) lesions.[1,18] The 9CST also discriminates patients with anterior lesions from HP. The 9CST significantly correlated with 79% of the subtests of a comprehensive neuropsychological battery and, accordingly, with an index of global cognition. Such a battery has been demonstrated to be a valid tool for detecting cognitive impairment, dementia, and ageing.[19–21] As a consequence, the 9CST can be considered a useful tool for such purpose. The 9CST reliability has also been confirmed;[1,18] in a test–retest study, for example, practice effect was not observed in the number of completed categories (i.e. the number of reached double arrays). As a consequence, the 9CST can be considered a useful index to assess disease evolution and treatment effectiveness in longitudinal studies. An association between the 9CST and the Wisconsin Card Sorting Test (WCST) and between the 9CST and academic achievement have been demonstrated as well.[1,22] An association between both card-sorting tests and an abbreviated version of the Raven test has also been demonstrated.[1,18,22] Unlike the Raven test, the 9CST enables the interviewees to be observed solving the problem, and not just the final result.[1]

In summary, the 9CST is a valid and reliable screening for executive function, intelligence, global cognition, and academic achievement. It is also useful for detecting cognitive impairment and dementia in the elderly, and for assessing disease evolution and treatment effectiveness. However, complementary studies with non-clinical samples are needed.

Objectives

This study aimed to describe 9CST performance in a non-clinical Argentinean sample, to analyze the effect of demographic variables, and to propose a suitable (i.e. the simplest and most homogeneous) cut-off point for possible deficits.

MATERIAL AND METHODS

Subjects

Participants were community-dwelling Argentinean volunteers without any known neurological or psychiatric disease (n = 164, 55% women). They were recruited from academic, cultural, recreational, and retirement centres in Cordoba, Argentina.[22,23] All the subjects gave informed consent. Before including a subject in the sample, we took into consideration the information provided in the initial interview from the neuropsychological battery. The initial interview is a very careful instrument that evaluates risk factors, background, and their probable incidence on cognition and behaviour. We excluded subjects who met any of the following criteria: (i) had symptoms of neurological or psychiatric disorders; (ii) consumed psychotropic drugs including excessive alcohol; (iii) had a risk of neurological damage from disease or an accident; (iv) had any kind of medical illness that could affect neuropsychological performance; and (v) had sensory or motor difficulties that could prevent subjects from carrying out the test fluently. School students who had repeated an academic year were also excluded.[22,23]

Material

The 9CST is part of a battery of neuropsychological tests abbreviated and adapted for Spanish speakers

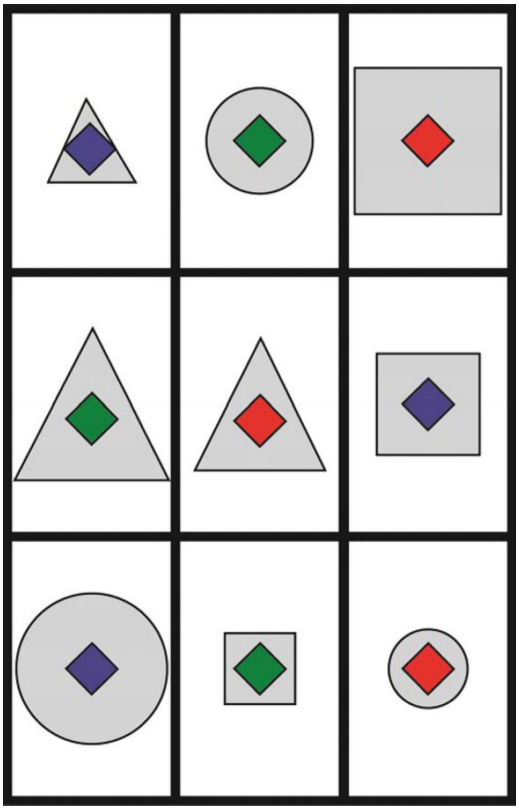

Figure 1 The Nine-Card Sorting Test stimulus cards in their initial position (i.e. not yet ordered).

(Fig. 1).[19–23] It is an easy to administer executive test,[1] the development of which considered the cognitive demands of previous sort and shift tests, as described by Lezak,[10] and seriation, classification and, correspondence, as set forth by Piaget.[24] The executive test involves a comprehensive, purposive, interviewee-centred, and novel activity that deals with three non-verbal sorting principles and their combination in pairs. In this task, multiple sub-goals (or steps) are subordinate to an overarching super-goal,[2,25] which is the best way of sorting. Interviewees do not have a reference model to reproduce, use, or complete, and the super-goal is suggested by the successive requirements of better (or new) arrays.

The 9CST correct simple arrays are: Form, Size, and Colour. The 9CST correct double (row × column combined) arrays are: Form and Colour (Size disordered), Form and Size (Colour disordered), and Colour and Size (Form disordered). It is impossible to combine three criteria at one time.[a]

The basic commands are as follows: (i) 'Order' (at the beginning); (ii) 'You can order better' (when the interviewee completed only a simple array); and (iii) 'Order in another way' (when the interviewee completed a double array). The reinforcements are 'well done' and 'very well done' for successful simple and double arrays, respectively.[b]

In the 9CST instructions, the interaction between interviewee and interviewer has been standardized. Briefly, the nine cards are put on the table as indicated in Figure 1. The task is presented as a game, and the basic commands may be complemented with additional or alternative expressions such as 'Let's play cards', 'These cards are mixed up and I want you to order them', 'Classify the cards'; 'Put the similar cards together'; 'You can order by rows and columns; 'You can order two criteria at a time'; and 'There are many ways of ordering'.[c] Interviewees can order the cards as they wish and should try to do their best.[d] Interviewees can begin with any of the correct arrays, and provided that the rectangle formed by the nine cards is respected, interviewees can organize the cards vertically or horizontally. Interviewees have to report when they believe they have completed one array.

In order to avoid an 'induced' performance, interviewers should never help interviewees by suggesting any of the criteria for a correct array. If an interviewee incorrectly believes he or she has completed a correct array, the interviewer can ask: 'How have you ordered the cards?' There are many possible arrays, but only the logically correct ones are reinforced. An aesthetic change in the spatial disposition of the cards (i.e. rotating the correct organization from vertical to horizontal, moving the same two criteria from row × column to column × row) does not represent a new array and should be considered as criterion repetition (another type of failure). Whenever an interviewee reports completing an array, the elapsed time and whether the array is correct or incorrect should be registered. In the present work, only the number of correct double arrays was analyzed. Each double array was considered a completed category, and one point was assigned to each completed category (range: 0–3). Failure to complete a category was scored as zero. As simple arrays were considered incomplete categories, they were scored with zero. Failures, time needed, and induced performance were not analyzed in this work.

The maximum administration time was usually 7 min, unless the interviewee was still working or trying to find a sorting principle when the 7 min had elapsed.[e]

Statistical analysis

Statistical tests were mainly carried out with χ^2 analysis. With the aim of getting better inferences and avoiding empty cells, we pooled original demographic groups whenever possible. Different age ranges were also pooled in order to try to find the simplest and most homogeneous cut-off points to report. Mostly descriptive information was taken into account when establishing these cut-offs. When the percentiles for the whole sample were determined, the 9CST performance was then expressed in just two categories: less or equal than the 25th percentile (P25) and greater than P25.

For informative purposes, factorial ANOVA were carried out using the total number of completed categories as the dependent variable. This was an attempt both to describe the effect of all the variables combined more clearly and to illustrate the results obtained by previous analyses.[f]

RESULTS

No significant difference in performance were found between the second and third levels of education (χ^2 = 4.08; degrees of freedom (d.f.) = 3; $P < 0.25$) or between men and women ($\chi^2 = 2.70$; d.f. = 3; $P < 0.44$). Therefore, those groups were pooled.[g] The six categories of age (χ^2 = 53.03; d.f. = 15; $P < 0.0001$) and the remaining categories of education ($\chi^2 = 30.72$; d.f. = 3; $P < 0.0001$) produced significant differences. Demographic data (with pooled gender and education groups) are shown in Table 1.

The median for the whole sample was 2, the P25 was 1, and the 75th percentile was 3.[h]

For cross-tabulation tables, the 9CST performance is expressed in two categories: (i) less or equal than P25 (values 0 and 1); and (ii) greater than P25 (values 2 and 3).

Table 1 Sample demographic data

	Education (*n*)		
Age	First level	Second and third level	Total (*n*)
0: 11–14 years	7	20	27
1: 15–29 years	8	58	66
2: 30–44 years	8	15	23
3: 45–59 years	12	11	23
4: 60–74 years	6	6	12
5: 75–90 years	7	6	13
Total	48	116	164

First level of education, primary school; second and third level of education, high school or higher. The six original age groups are shown. Men and women were pooled. Mean ± SD age of sample: 33.13 ± 21.54 years.

Trying to find the simplest and most homogeneous cut-off points to report, we pooled different age ranges. The best descriptive age ranges for purposes of this study were younger than 45 years old (age 1), between 45 and 74 years old (age 2), and older than 74 years old (age 3).[i]

Table 2 shows that the 45–74 age range (the middle/transitional age in performance) had about 50% of the subjects above and below the P25; the other age ranges (i.e. subjects younger than 45 and older than 74) showed an opposite pattern between one another, with the majority positioned either above or below the P25. The apparently different education patterns observed throughout the age ranges were intentionally searched with the selected cut-off points by using descriptive/qualitative information and statistical trends. However, given the individual median within each age range (which was independently analyzed by the median

Table 2 Age × education × performance cross-tabulation

Age	Education	9CST ≤ P25 score ≤ 1	9CST > P25 score ≥ 2	Row totals
<45 years	1	9 39.13%	14 <u>60.87%</u>	23 47.92%
<45 years	2	8 8.60%	85 <u>91.40%</u>	93 80.17%
Total row count		**17**	**99**	**116**
Total row percentage		14.66%	**85.34%**	
45–74 years	1	12 <u>66.67%</u>	6 33.33%	18 37.50%
45–74 years	2	6 35.29%	11 <u>64.71%</u>	17 14.66%
Total row count		**18**	**17**	**35**
Total row percentage		**51.43%**	**48.57%**	
>74 years	1	5 <u>71.43%</u>	2 28.57%	7 14.58%
>74 years	2	4 <u>66.67%</u>	2 33.33%	6 5.17%
Total row count		**9**	**4**	**13**
Total row percentage		**69.23%**	30.77%	
	Column total	**44**	**120**	**164**

Score range: 0–3. Row counts and percentages are shown. The total row percentages showing the majority (or closer to the 50%) of the total cases above and below the P25 are in bold. Total row counts are also shown in bold. The six original age groups were pooled trying to find the most representative performance groups according to educational influence. The percentages showing the majority of the education cases throughout the age ranges are underlined. However, only the age group <45 years produced a significant education effect (considered as a whole) in this table; more specific analyses of the education effect within each age group did not produce significant differences. 9CST, Nine-Card Sorting Test; education 1, primary school; education 2, high school or higher; P25: 25th percentile.

Table 3 Percentiles for different levels of age and education

Age, education	P25	P50	P75
Age 1, edu 1	1	2	3
Age 1, edu 2	2	2	3
Age 2, edu 1	0	1	2
Age 2, edu 2	1	2	3
Age 3, edu 1	0	1	2
Age 3, edu 2	1	1	2

Age 1, <45 years old; age 2: 45–74 years old; age 3: >74 years old; edu 1, primary school; edu 2, high school or higher; P, percentile.

test), significant education differences were not observed for any of the three ages considered independently (all $\chi^2 \leq 3.44$; d.f. = 1; $P \geq 0.06$).

By only considering the age of 45 years old as the cut off point, the ageing effect was expressed in two categories as follows (see also Table 2): (i) 120/164 subjects (73%) had a 9CST score ≥2, from which only 21 (17%) were ≥45 years old; and (ii) 44/164 subjects (27%) had a 9CST score <2, from which 27 (61%) were ≥45 years old ($\chi^2 \geq 29.92$; d.f. = 1; $P \leq 0.0001$). Education effects under this cut-off point showed an almost identical pattern to that reported above, i.e., significant education differences were not observed within any of both age groups considered independently ($\chi^2 \leq 2.93$; d.f. = 1; $P \geq 0.09$). This result confirmed that the education effect throughout the specific age ranges was homogeneously distributed.

Given the significant effects of age and education and the lack of gender effect, the simplest cut-off points to report were as follows (Table 3): (i) the median (50th percentile) for people younger than 45 years old was 2, independent of the educational level; (ii) the median for people older than 74 years old was 1, independent of the educational level; and (iii) the median for people between 45 and 74 years old was 1 for the first level of education and 2 for higher levels of education.

Using these three categories of age, a gender × education × age ANOVA was carried out. This confirmed a significant main effect of age and education, but the main effect of gender was not significant. Significant interactions among demographic variables were not observed (Table 4). A two-way education × age ANOVA was also carried out to describe the two significant effects: education ($F_{1,158} = 9.76$, $P < 0.0021$); age ($F_{2,158} = 10.31$, $P < 0.0001$); and education × age interaction ($F_{2,158} = 1.11$, $P < 0.3323$). The graph representing 9CST performance as a function of age and education is shown in Figure 2.

Table 4 ANOVA summary: univariate tests of significance for number of categories

	SS	d.f.	MS	*F*	*P*-value
Gender	0.96	1	0.96	1.43	0.2343
Education	**7.05**	**1**	**7.05**	**10.43**	**0.0015**
Age	**12.27**	**2**	**6.14**	**9.09**	**0.0002**
Gender × education	0.04	1	0.04	0.06	0.8024
Gender × age	1.28	2	0.64	0.95	0.3897
Education × age	1.09	2	0.54	0.81	0.4487
Gender × education × age	0.09	2	0.05	0.07	0.9346
Error	102.64	152	0.68		

Significant results are shown in bold. SS, Sum of squares; d.f., degrees of freedom; MS, Mean of squares (SS/d.f.).

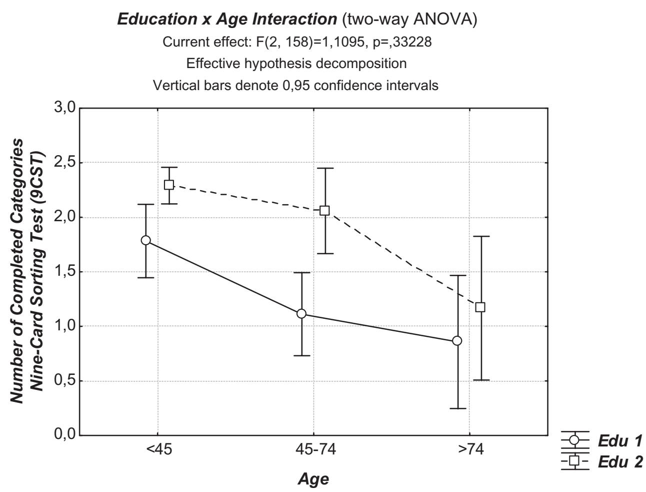

Figure 2 Number of completed categories in the 9CST: education × age interaction. Edu 1, primary school; Edu 2, high school or higher.

As a final remark, it is worth mentioning that all the inferential results of this work did not change with the different cut-off points explored (data not shown but available upon request).

DISCUSSION

By considering both the statistical nature of the dependent variable (i.e. the number of completed categories) and the clear-cut performance observed in the different studied samples, the 9CST can be defined as a categorical screening for executive function and global cognition.

The present results indicated that the P25 (equivalent to one double array) can be a valid index for inferring possible deficits. Most of the participants got a score of two double arrays or above, except for people older than 44 years old with first level education and people older than 74 years old. About 85% of participants younger than 45 years old got a score of two double arrays or above. Therefore, the presence of the studied ability was well represented by one performance value. Below that value, there may be a cognitive risk that should be studied more carefully.

Complementary 9CST studies with HP significantly determined both the presence of neurological or psychiatric risk and primary school dropouts within the P25,[26] thus indicating the viability of the 9CST to detect behaviours that may be potentially deleterious for neurocognitive functioning. Additionally, in previous validity studies with clinical and non-clinical samples,[1] the value of one double array (the common median in such three samples) represented a cut-off point that significantly discriminated between anterior lesions, posterior lesions, and HP samples.

In the present sample of HP, the 9CST performance turned out to be unexpectedly homogeneous, and the proposed cut-off points aimed to make this feature more evident. Such homogeneity represents an advantageous outcome for this screening test because the effect of intervening factors was fairly attenuated by the dominance or representativeness of one categorical value. However, as expected of a test that assesses executive function and global cognition, the effects of age and education were still significant.

A gender difference was not observed at all, which is consistent with previous studies that have reported that men and women have similar results on intelligence or global cognition tests. The greater cognitive impairment observed for women in old age may depend on the task involved and/or environmental conditions.[17] In a previous study from our laboratory in which healthy subjects were evaluated with a picture-naming test, a lower performance was observed in women who were older, and within this group, in those with a lower level of education.[11] Although the picture-naming test required both verbal and visual semantic knowledge, it is not a complex neurocognitive task and does not involve fluid intelligence.

In contrast, and as expected, the vulnerability of the present complex neurocognitive task with regard to ageing was confirmed. This effect seemed to be evident in those aged 45 and older, and it was more noticeable in those with a lower level of education. This early ageing effect is similar to what has been observed in the performance scale of the Wechsler Adult Intelligence Scale and in executive, prefrontal, and spatial working memory functions with increasing age.[3,5,7–10]

Although the education effect on 9CST turned out to be statistically significant in all the statistical figures of the present study, it seems that its protective effect against ageing was a less relevant for people older than 74 years old. Specifically, when the current sample of HP is considered as a whole, it can be concluded that this age group had a greater presence of persons with global neurocognitive risk. Moreover, this was the only age range that did not get the maximum score (i.e., the third double criterion) under the studied percentiles.

Categorical cut-off points have serious psychosocial implications in clinical and non-clinical settings because subtle differences are interpreted as absolute by the persons involved.[27] It is well known that the longer the psychological tests, the better the psychometric properties.[28] However, the decision to diagnose a person as being at risk can be arbitrary when the cut-off point has been made from a wide range of possibilities as in a quantitative scale. The use of efficient (brief, valid, and reliable) categorical scales for making categorical evaluations may be a good option when the benefits outweigh the costs (i.e. when it can be demonstrated that few categories transmit relevant information). In the 9CST, few categories have been shown to transmit relevant information in view of the number of psychological and sample attributes that those categories encompass.

The test is also fruitful for studies on visuospatial organization.

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ENDNOTES

[a]Details of test construction and comparisons with other card-sorting tests are explained elsewhere.[1]

[b]In the 9CST, when two double arrays have been reached, the simple array that has been chosen twice becomes ‘dominant’. Therefore, the facilitatory and inhibitory mechanisms involved in the visuospatially dominant response can be seen throughout the session.

[c]The initial interview is a good way to establish a friendly interaction with interviewees and to verify their willingness to perform the tests. (In our laboratory, the 9CST has always been administered with the initial interview and other tests.) When a good rapport has been established and the first command has been expressed, the lack of motivation to sort the cards, which is reported by the interviewees specifically in relation to this task, is interpreted as a lack of aptitude (i.e. as one behavioural index of the impossibility to do the task).
[d]Interviewees can organize the cards in the same way they would organize other items, such as shoes or clothes. Even aphasic patients, preschool children, and illiterate persons can perform the task. When verbal interaction is insufficient, pointing at the cards/criteria can replace (or complement) talking about the cards/criteria.
[e]If possible, interviewees should be encouraged to find criteria within 7 min, the maximum time when the impossibility to find better (or new) arrays is evident. The stopwatch should not be paused once the first command has been made, and it should continue until the interviewee finishes the task by expressing that it is impossible to continue.
[f]Non-parametric ANOVA were also carried out (with the same dependent variable) to reveal the details of the effect of all the independent variables and their categories.
[g]These results were also verified by the Kruskal–Wallis ANOVA by Ranks. None of the comparisons between the second and third levels of education produced significant differences for each age group or gender. In addition, none of the comparisons between men and women, including analyses of the whole sample and for each level of education and age, produced significant differences.
[h]When 15 persons who did not achieve any criterion (80% > 44 years old) are excluded, the time of administration to achieve the maximum number of criteria was 253.88 ± 170.54 s.
[i]Within each pooled age range, all pairwise comparisons for the six age groups discriminated for each level of education, did not produce significant differences according to Kruskal–Wallis ANOVA by Ranks.

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