British Journal of Clinical Psychology (1999), **38**, 27–41 *Printed in Great Britain*

Performance on the Modified Card Sorting Test by normal, healthy individuals: Relationship to general intellectual ability and demographic variables

M. C. Obonsawin*
Department of Psychology, University of Strathclyde, Glasgow

J. R. Crawford, J. Page, P. Chalmers, G. Low and **P. Marsh**
Department of Psychology, University of Aberdeen, Aberdeen

Objectives. The aim of this study was to obtain normative data for the Modified Card Sorting Test (MCST), and to examine the relationship between performance on this task, general intellectual ability and demographic variables.

Design. A sample of 146 healthy individuals was tested with a demographic distribution (age, sex, socioeconomic class) similar to that of the British population.

Methods. The MCST and the Wechsler Adult Intelligence Scales – Revised were administered to 146 people aged between 16 and 75 years.

Results. Most people (56.6%) completed six categories, and many people made perseverative errors. Approximately 8% of the participants made over 50% perseverative errors. Performance on the MCST varied with age, years of education and general intellectual ability. Individuals with a Full Scale Intelligence Quotient (FSIQ) below 100 showed much more variability in performance than individuals with an FSIQ over 100. Detailed percentile norms for the performance on different indices of the test are presented.

Conclusions. The performance of individuals on the MCST is more closely associated with general intellectual ability than with demographic variables.

The Modified Card Sorting Test (MCST; Nelson, 1976) was introduced as a simplified version of the Wisconsin Card Sorting Test (WCST; Grant & Berg, 1948). The MCST was to improve on the WCST by: (i) simplifying the task for the individual being tested, thereby avoiding frustration and non-compliance; (ii) removing the ambiguity in interpreting responses on the test; and (iii) providing a

* Requests for reprints should be addressed to Dr Marc C. Obonsawin, Department of Psychology, University of Strathclyde, Graham Hills Building, 40 George Street, Glasgow G1 1QE, UK.

measure of perseveration that would discriminate between individuals with lesions in the frontal lobes from other individuals more consistently than the perseveration measures of the WCST. There have been fears expressed that the MCST is a very different test and may be measuring different psychological functions than does the WCST (Lezak, 1983, p. 492). However, there is now some evidence, albeit sparse, that performance on the two tests is highly associated (Greve & Smith, 1991). Since its introduction, the MCST has been used clinically and experimentally to assess the function of the frontal lobes (for a review, see de Zubicaray & Ashton, 1996).

The performance of healthy people on the WCST has been and continues to be well researched. Heaton, Chelune, Talley, Kay & Curtiss' (1993) manual provides detailed descriptions of the performance of 899 healthy people on the WCST, and the relationship of their performance with intellectual ability, as estimated by the Wechsler Adult Intelligence Scales – Revised (WAIS–R) and demographic variables like age, sex, social class and the number of years of education. More recent studies have provided information on the association between education and performance on the WCST (Stratta, Rossi, Mancini, Cupillari, Mattei & Casacchia, 1993) and have provided information on developmental changes in performance of the task (Boone, Ghaffarian, Lesser, Hill-Gutierrez & Berman, 1993; Chelune & Baer, 1986; Fristoe, Salthouse & Woodard, 1997; Paniak, Miller, Murphy, Patterson & Reizer, 1996; Rosselli & Ardila, 1993; Salthouse, Fristoe & Rhee, 1996).

In contrast to the research on the WCST, there are few reports that describe the performance of healthy people on the MCST, or that describe the relationship between performance on the MCST and demographic variables or general intellectual ability. In most reports (Bondi, Monsch, Butters, Salmon & Paulson, 1993; Gotham, Brown & Marsden, 1988; Joyce & Robbins, 1991; Parkin & Walter, 1991, 1992; Paus *et al*., 1991; van den Broek, Bradshaw & Szabadi, 1993; Van der Linden & Bruyer, 1992), the performance of healthy individuals on the MCST is reported because these individuals are control participants in a broader experiment. In only one of the reports (Nelson, 1976) is the primary aim to provide a description of the MCST. Unfortunately, there are at least four major reasons why the normative scores described in these reports are difficult to interpret.

First, in most of these studies, the performance of the healthy participants on the various measures of the MCST (number of categories obtained, number of perseverative errors, percentage of perseverative errors) is reported with means and standard deviations, despite the fact that the distributions of scores for these measures are not normally distributed, but are highly skewed. The mean and standard deviation of such skewed distributions are very difficult to understand, and may in fact be misleading. Only Nelson (1976) and van den Broek *et al*. (1993) report on the number of healthy participants with 50% or more perseverative errors, and only Nelson provides information of the distribution of the number of categories obtained.

Second, in those studies that include a measure of intellectual ability, the measure is either the unrevised version of the Wechsler Adult Intelligence Scales (WAIS; Joyce & Robbins, 1991; Nelson, 1976), a short form of the WAIS (van den Broek *et al*., 1993), or the National Adult Reading Test (Parkin & Walter, 1991, 1992), but in no study is the WAIS–R used. Third, the number of healthy participants in most

studies was very small, ranging from 15 (Gotham *et al*., 1988) to 46 (Nelson, 1976) healthy individuals. The two largest studies that have reported on the performance of healthy individuals on the MCST are those by Bondi *et al*. (1993) and van den Broek *et al*. (1993), who studied 75 and 77 healthy participants, respectively.

The fourth difficulty in presenting normative data of performance on the MCST arises in presenting data on the percentage of perseverative errors, the one measure that is thought to reflect frontal lobe dysfunction (Milner, 1963; Nelson, 1976). The difficulty originates in the fact that some healthy individuals may make very few errors, but a high percentage of these errors may be perseverative. These perseverative errors do not interfere seriously with the ability to complete the task, but they illustrate that some individuals can successfully complete the task and achieve a high percentage of perseverative errors. Indeed, some healthy individuals successfully complete the task yet obtain more than 50% perseverative errors, which according to Nelson's (1976) criteria suggests frontal lobe dysfunction. For this reason, some investigators present the percentage of perseverative errors only of participants completing fewer than six categories (Nelson, 1976; van den Broek *et al*., 1993); some prefer to present the percentage of perseverative errors of all healthy participants (Bondi *et al*., 1993; Gotham *et al*., 1988; Paus *et al*., 1991); and yet other investigators include the number of perseverative errors, but not the percentage (Joyce & Robbins, 1991; Parkin & Walter, 1991, 1992). It has been argued that the percentage of perseverative errors of individuals completing six categories should not be considered separately from those participants completing fewer than six categories, and that the failure to include the percentage of perseverative errors of individuals able to complete the task successfully underestimates the classification accuracy of the MCST (de Zubicaray & Ashton, 1996).

In this study, the MCST was administered to 146 healthy individuals to investigate the extent to which performance on the task was associated with intelligence, age, sex, education and social class. To assure heterogeneity in the sample of healthy individuals, the participants were recruited so as to match the demographic characteristics of the British population. All participants received the full version of the WAIS–R. The percentage of perseverative errors of all participants, and of those obtaining fewer than six categories, were examined separately. The aims of this research were to provide information on some of the factors associated with the performance of the task, and to provide a standard with which to compare the performance of individuals from psychiatrically or neurologically impaired populations.

Method

Participants

Participants ($N = 146$) were recruited from the community and received an honorarium for their participation. To assure the recruitment of the appropriate number of participants from each of the socioeconomic groups, participants were recruited from private companies, public service institutions and employment centres. Potential participants were excluded if they had ever been hospitalized for a mental illness, had ever suffered from alcoholism, a serious head injury, a stroke or a neurological condition, or if they were currently receiving medical treatment for anxiety or depression. The demographic characteristics of the sample are shown in Tables 1, 2 and 3, and are compared to the demographic characteristics of the population of Great Britain at the 1981 Census. The mean

Table 1. Percentage of participants in this sample ($N = 146$) and of Great Britain (according to the 1981 Census) in each of the five socioeconomic classes

	Social Class				
	1	2	3	4	5
Sample	5	29	45	12	10
Great Britain	4	22	48	19	7

Table 2. Percentage of participants in this sample ($N = 146$) and of Great Britain (according to the 1981 Census) according to age and sex

	Age			Sex	
	16–34	35–59	60+	Male	Female
Sample	42	45	12	53	47
Great Britain	37	45	18	48	52

Table 3. Performance on WAIS–R and years of education of participants

	Mean (SD)	Range
FSIQ	105.34 (14.13)	70–141
VIQ	105.64 (13.97)	72–143
PIQ	103.87 (14.11)	68–140
Education	12.38 (2.28)	8–20

(±standard deviation) age of the participants was 40.3 (±14.0) years, and ranged from 16 to 75 years. The definition of social class was based on occupation, as defined by the Office of Population Censuses and Surveys (1991). The social classes were: (1) (professional), (2) (managerial), (3) (skilled, non-manual and manual), (4) (partly skilled) and (5) (unskilled). The number of years of education was calculated by adding the total number of years of full-time education, and allowing 0.25 of a year for each year of part-time education.

Procedure

Each participant was administered the full version of the WAIS–R (Wechsler, 1981) and the MCST. The MCST was administered and scored as described by Nelson (1976). The cards were always presented to the participants in the same order, according to the sequence provided by the numbers at the back of the cards. Errors were scored as perseverative if the sorting response was the same category (colour, form, number) as the previously incorrect response, or if the sorting response did not change after the subject was told that the rules had changed. An error was not scored as perseverative if the subject followed a sorting response to neither colour, form or number (an 'other' response) with a second 'other' response. In this situation, the examiner does not know the rationale behind the sorting response, and so cannot be sure that the response is perseverative.

Statistical analysis

Because of the non-gaussian distribution of scores on the MCST, all statistical analyses were non-parametric. As there is no procedure for partial correlation using Spearman's *rho*, Kendall's *tau* was used to allow calculation of Kendall's partial *tau* (Kendall & Gibbons, 1990). Tables to estimate the statistical significance of Kendall's partial *tau* were obtained from Maghsoodloo & Pallos (1991).

Results

Number of categories obtained

In all, 83 of the 146 participants (56.8) performed at ceiling and completed the six categories (Fig. 1). However, 43.2% of the participants did not manage to do so.

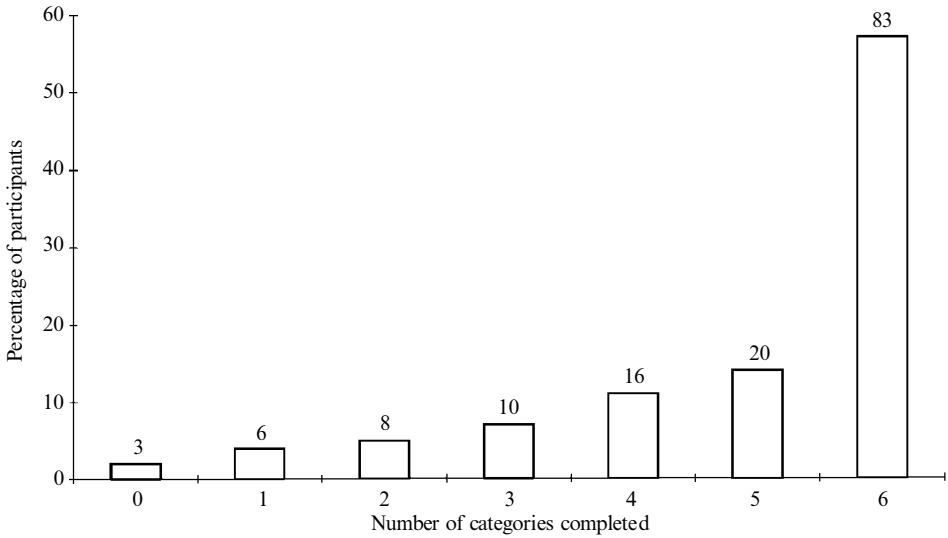

Figure 1. Number of categories completed by all participants (– 146). The number above each bar represents the number of participants completing the indicated number of categories.

There is a much larger number of people completing six categories than there is completing five categories, but as the number of categories completed decreases from five to zero, the number of people completing these categories decreases gradually. A Mann–Whitney *U* test demonstrated that there was no sex differences in the number of categories obtained ($p = .99$).

Types of errors

The distributions of non-perseverative and perseverative errors are positively skewed (Fig. 2), and analysis with a Wilcoxon Matched-Pairs Signed Ranks test demonstrated that non-perseverative errors accounted for most of the errors ($z = -6.59$, $p < .00005$). According to Milner (1963) and Nelson (1976), the most

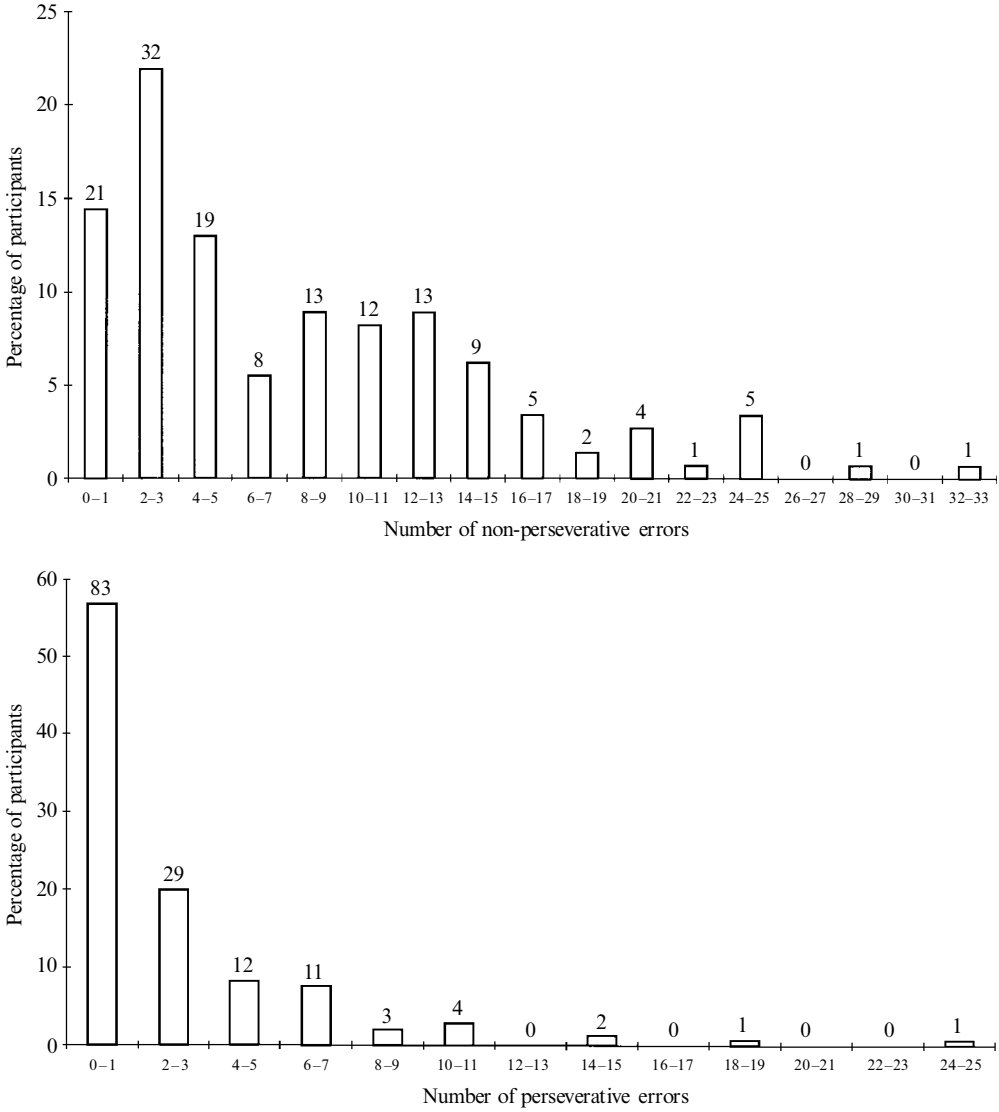

Figure 2. Non-perseverative (upper panel) and perseverative (lower panel) errors in all participants (– 146). The numbers on the abscissa indicate the range of errors for each bar of the histogram. The number above each bar represents the number of participants in each range.

significant measure of both the Wisconsin and Modified Card Sorting tests is the percentage of errors that are perseverative. Of the 146 participants who were administered the MCST, 59 (40.4%) made no perseverative errors and consequently had 0% perseverative errors. As seen in Figure 3 (upper panel), 67 of the participants (45.9%) made less than 10% perseverative errors. The percentage of perseverative errors ranged from 0 to 75. Twenty-five of the participants (17.1%) made 35%

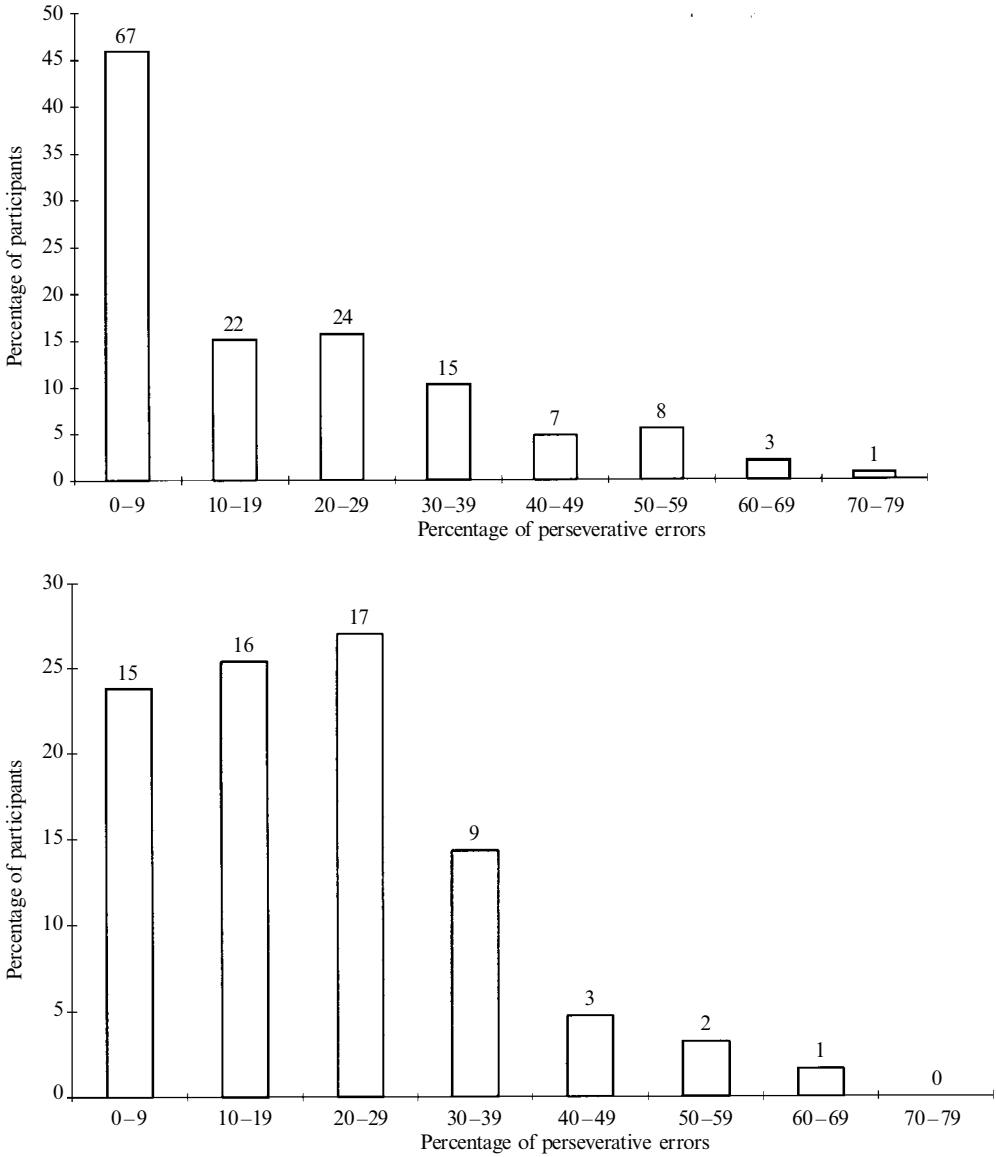

Figure 3. Percentage of perseverative errors in all participants (– 146, upper panel) and in participants completing fewer than six categories (– 63, lower panel). The numbers on the abscissa indicate the range of errors for each bar of the histogram. The number above each bar represents the number of participants in each range.

perseverative errors or more, and 12 of the participants (8.2%) made 50% or more perseverative errors.

Of the 83 participants who successfully completed six categories, 52 (62.7%) made no perseverative errors, but the remaining 31 participants (37.3%) made between one and a maximum of five perseverative errors. Although these participants

produced only a small number of perseverative errors, they nevertheless produced a range of between 10% and 75% perseverative errors, with nine participants obtaining 50% or more perseverative errors. The distribution of the percentage of perseverative errors for those individuals completing fewer than six categories is shown in Figure 3 (lower panel). The percentage of perseverative errors ranged between 0 and 62.5%, with a mode of 20%. Three participants (5%) obtained 50% perseverative errors or more, and 11 participants (18.3%) obtained 35% perseverative errors or more. Mann–Whitney *U* tests demonstrated that there were no sex differences in either the number of perseverative errors ($p = .57$) or the percentage of perseverative errors ($p = .18$ for all participants; $p = .06$ for participants completing fewer than six categories). Percentile norms for the number of categories achieved, the different types of errors, and the percentage of perseverative errors on the MCST are presented in Table 4.

Table 4. Percentile norms for the MCST, for individuals between the ages of 16 and 75 years

Percentile	Categories completed	Non-perseverative errors	Perseverative errors	% perseverative errors, all participants	% perseverative errors, participants with fewer than six categories
>99	6	0	0	0	0
99	6	0	0	0	0
95	6	1	0	0	0
90	6	1	0	0	0
85	6	2	0	0	8
80	6	2	0	0	9
75	6	3	0	0	11
70	6	3	0	0	14
65	6	3	0	0	17
60	6	4	1	6	18
55	6	5	1	9	19
50	6	6	1	14	20
45	6	8	1	17	21
40	5	8	2	19	22
35	5	10	2	22	25
30	4	11	3	25	29
25	4	12	3	29	29
20	4	13	4	33	31
15	3	15	6	38	36
10	2	18	7	43	40
5	1	24	10	50	50
1	0	28	18	75	>63
<1	0	>28	>18	>75	>63

Note. The percentile rank for each measure should be read separately. The same individual may obtain 40% perseverative errors (10th percentile) yet complete six categories (>45th percentile).

Association between general intellectual ability, demographic variables and performance on the MCST

The relationships between the general intellectual ability and demographic indices of the participants, and their performance on the measures of the MCST that are held to be important measures of frontal lobe function were examined. Unless indicated to the contrary, the measure of general intellectual ability was not corrected for age, and all correlations involving the Full Scale Intelligence Quotient (FSIQ), the Verbal Intelligence Quotient (VIQ) and the Performance Intelligence Quotient (PIQ) were calculated with the sum of scaled scores before age-grading. In this way, the performance of participants on the MCST can be compared to their performance on the WAIS–R without the age variable confounding the comparison, and the age variable can be used as a variable in its own right. The results are shown in Kendall correlation matrices (see Tables 5 and 6).

Table 5. Association between demographic variables and performance on the MCST: Kendall *tau* correlations and partial *tau* correlations with FSIQ

	Covariates					
	None			FSIQ[1]		
	Age	Class	Education	Age	Class	Education
Number of categories	**−.28**	**−.27**	**.36**	**−.19**	−.07	**.16**
Number of perseverative errors	**.23**	**.21**	**−.31**	**.13**	.04	**−.13**
% perseverative errors[2]	**.20**	**.13**	**−.23**	**.15**	.03	**−.16**
% perseverative errors[2,3]	.02	.07	−.17	−.01	−.01	−.10

Note. Kendall's *tau* and partial *tau* correlations in **bold** type are all significant at the .05 level. FSIQ = Sum of scaled scores (not age-graded) of all subtests on the WAIS–R.

[1] The scores used were the sum of scores on the subtests of the Verbal and Performance Scales before age-grading.

[2] To use this proportion in statistical analysis, the authors transformed the percentage with an arcsin square root transformation.

[3] Only participants obtaining fewer than six categories are included ($N = 63$).

All three demographic variables (age, social class and education) correlated modestly but significantly with the number of categories completed, the number of perseverative errors, and the percentage of perseverative errors (for all participants), but not with the percentage of perseverative errors for participants completing fewer than six categories (see Table 5). Performance on the WAIS–R, as shown by the scaled scores, not age-graded, from the FIQ, the VIQ and the PIQ scales, correlated moderately with the number of categories obtained and the number of perseverative errors, and modestly but significantly with the percentage of perseverative errors (for all participants – see Table 6). Only performance on the subtests of the VIQ correlated significantly with the percentage of perseverative errors of participants obtaining fewer than six categories, and this correlation was very low (see Table 6).

Table 6. The association between performance on the WAIS–R and performance on the MCST: Kendall *tau* correlations and partial *tau* correlations with age

	Covariates					
	None			Age		
	FSIQ[1]	VIQ[1]	PIQ[1]	FSIQ[1]	VIQ[1]	PIQ[1]
Number of categories	**.45**	**.38**	**.45**	**.36**	**.33**	**.30**
Number of perseverative errors	**−.36**	**−.34**	**−.31**	**−.30**	**−.31**	**−.22**
% perseverative errors[2]	**−.23**	**−.23**	**−.17**	**−.19**	**−.21**	−.11
% perseverative errors[2,3]	−.17	**−.19**	−.07	−.16	**−.19**	−.06

Note. Kendall's *tau* and partial *tau* correlations in **bold** type are all significant at the .05 level.
FSIQ = Sum of scaled scores (not age-graded) of all subtests of the WAIS–R; VIQ = Sum of scaled scores (not age-graded) of all subtests of the Verbal Scale of the WAIS–R; PIQ = Sum of scaled scores (not age-graded) of all subtests of the Performance Scale of the WAIS–R.
[1] The scores used were the sum of scores on the subtests of the Verbal and/or Performance Scales before age-grading.
[2] To use this proportion in statistical analysis, the authors transformed the percentage with an arcsin square root transformation.
[3] Only participants obtaining fewer than six categories are included ($N = 63$).

It is well known that the demographic variables of age, social class and education all contribute to the variability in general intellectual ability. To parse out their contribution to the performance on the MCST, partial correlations were carried out using Kendall's partial *tau*. After controlling for performance on the WAIS–R, the correlations between social class and the MCST measures decrease substantially and become negligible (see Table 5). The correlations between the number of years of education and age with all MCST measures also decrease considerably after partialling out the performance on the WAIS–R, but they remain significant (see Table 5). The contribution of general intellectual ability to the number of categories obtained decreases when age is a covariate (see Table 6), but remains moderate and significant. As expected, introducing age as a covariate decreases the relationship between the MCST measures and the subtests of the PIQ scale of the WAIS–R, but causes only little change to the relationship between the performance on the subtests of the VIQ scale and performance on the MCST (see Table 6).

The relationship between general intellectual ability and performance on the MCST is better appreciated by examining Figure 4. This figure reveals that, as a group, individuals with an FSIQ (age-graded) above 100 show less variation in the number of categories obtained on the MCST, and the percentage of perseverative errors than individuals with an FSIQ below 100. Mann–Whitney U tests demonstrate that individuals with an FSIQ of 103 or below (median split) obtain fewer categories ($U = 1533$, $p < .0001$) and have a higher percentage of perseverative errors ($U = 1911.5$, $p = .0023$) than individuals with an FSIQ over 104. If only individuals with fewer than six categories are analysed, the percentage of perseverative errors in the low and high IQ groups are not significantly different ($U = 324$, $p = .2173$).

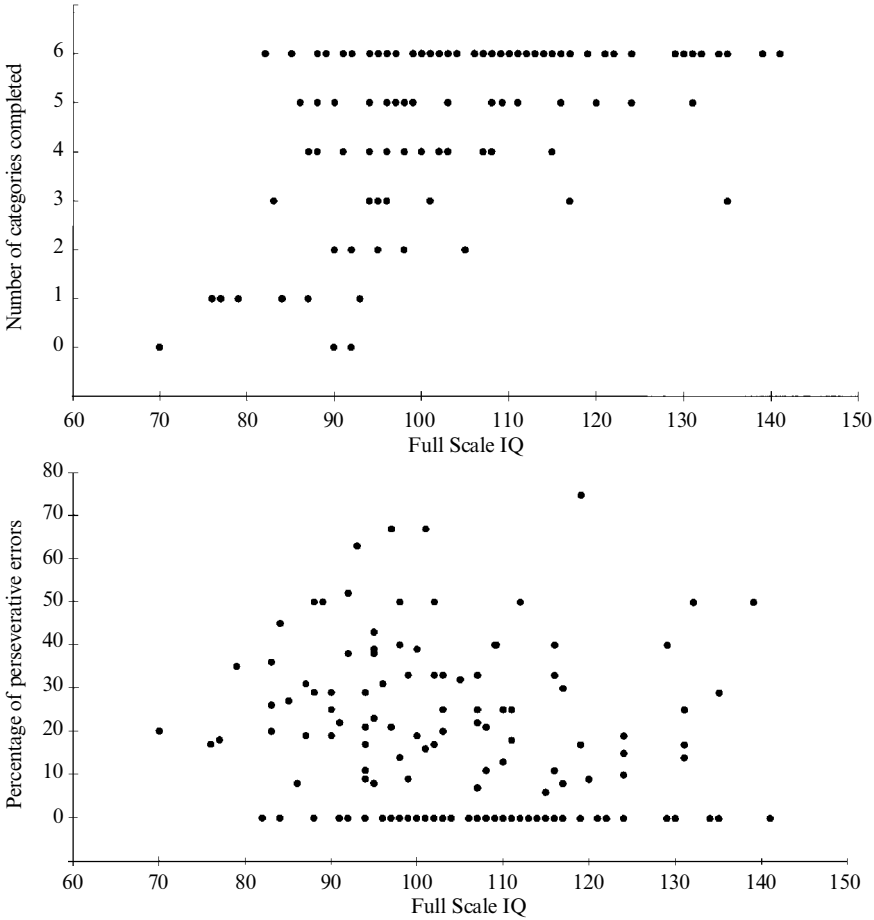

Figure 4. Relationship between Full Scale IQ (age-graded) and the number of categories obtained (upper panel) and the percentage of perseverative errors (lower panel) in all participants (– 146).

Discussion

A recent review of the existing normative data on the MCST is provided by de Zubicaray & Ashton (1996). Of the nine reports cited, those with the highest number of participants were Bondi *et al*. (1993) ($N = 75$) and van den Broek *et al*. (1993) ($N = 77$). In none of these reports was the performance of the healthy individuals compared to their performance on the WAIS–R. In the present study, 146 healthy participants from the community, with a demographic distribution similar to that of the British population, performed the MCST and the WAIS–R.

The results show that 43% of healthy participants from a wide range of ages, social classes and educational attainment obtain five or fewer categories. This proportion appears higher than the 32.6% (Nelson, 1976) or 37.7% (van den Broek *et al*., 1993) of participants who completed five or fewer categories in previous studies. Unsuccessful completion of the six categories can be owing either to

excessive non-perseverative errors and/or to excessive perseverative errors. Most errors made by the healthy participants in the sample were non-perseverative, and so unsuccessful performance on the task was probably owing to an inability to understand the nature of the task, to understand the concepts, or to remember previous responses.

In contrast to the WCST, in which very few people (>99th percentile) make no perseverative errors (Heaton *et al*., 1993), about 40% of healthy individuals make no perseverative errors at all on the MCST, and consequently attain 0% perseverative errors. One of the reasons for this difference lies in the fact that in the MCST, individuals receive a warning that the category rule is changing before they sort the card to the new category. In the WCST, individuals learn of the rule change only after they have sorted the card, so that the first sort after the rule change is likely to be a perseverative error. A minimum of six perseverative errors is therefore expected in the WCST, and so the test procedure artificially increases the number of perseverative errors. Whereas Nelson (1976) overcame this problem by providing a warning of a rule change in the MCST, Burgess & Shallice (1996), in a similar task, dispensed with the warning but changed the scoring procedure. In their Brixton spatial anticipation test, the first response that follows an unwarned rule change is scored as correct if that response follows the previous rule. If the scoring of the WCST was altered in this way, the number of perseverative errors would provide a more accurate measure of the extent of perseveration.

In both the WCST and the MCST, the measure that putatively differentiates individuals with focal lesions from individuals with focal non-frontal lesions is the degree of perseveration as assessed by the proportion of errors that are perseverative (Heaton *et al*., 1993; Milner, 1963; Nelson, 1976). The percentage of perseverative error score on the WCST is the proportion of all the trials that are perseverative errors, whereas the percentage of perseverative error score on the MCST is the proportion of all the errors that are perseverative. In her original presentation of the MCST, Nelson (1976) recommended a cut-off score of 50% perseverative errors to differentiate individuals with lesions in the frontal lobes from individuals with no lesions in the frontal lobes, or from healthy participants. None of her 15 control participants with five or fewer catebories obtained 50% perseverative errors, and only 5% of individuals with non-frontal lesions reached the 50% cut-off score. In the present study, carried out on a larger and more heterogeneous sample of healthy participants, three of the 63 (4.8%) healthy participants with five or fewer categories obtained 50% or more perseverative errors. The total number of errors in these three participants ranged between 14 and 40. Although these results demonstrate that healthy participants show little tendency to perseverate, they do show that some participants with no neurological history can have a high proportion of perseveration errors.

Although some investigators (Nelson, 1976; van den Broek *et al*., 1993) have argued that only the percentage of perseverative errors of participants completing fewer than six categories should be considered, other writers (de Zubicaray & Ashton, 1996) have argued that the percentage of perseverative errors of individuals completing six categories should be included in the analysis of percentage of perseverative errors to establish an appropriate cut-off score that would differentiate

individuals with lesions to the frontal lobe from individuals with no lesions or with lesions elsewhere. Nelson had set the cut-off score at 50% perseverative errors. In the present sample of healthy individuals, 50% perseverative errors indicates the eight percentile for all participants, and the fifth percentile for those participants obtaining fewer than six. In healthy participants therefore, the inclusion of participants completing six categories does not seriously alter the percentage of people obtaining more than 50% perseverative errors.

Most other reports providing normative information on the MCST do so with parametric descriptives (mean and standard deviation). The use of means and standard deviations to describe the performance and variation in performance of a group of individuals on the MCST is clearly inadequate. A standard deviation is only useful if the distribution is gaussian. This paper provides percentile norms that should help with the interpretation of an individual's performance on the MCST.

Knowledge of some of the factors associated with the performance of the MCST would not only help in the interpretation of an individual's performance on the test, but may also help in defining the cognitive mechanisms underlying performance on the task. In this sample of healthy individuals recruited from a wide range of ages and social classes, variables such as intellectual ability, age and education correlated with various aspects of the performance on the MCST, as they do with the same aspects of performance on the WCST. To test the possibility that the contribution of age and education to the variability of performance on the MCST was really mediated by intellectual ability, the age and education correlations were also covaried with performance on the WAIS–R. The fact that age and education, but not social class, still correlate significantly with performance on the MCST after covarying with WAIS–R performance suggests that the contribution of age and education to performance on the MCST is not fully mediated by intellectual ability, and/or that the WAIS–R is an imperfect measure of intellectual ability.

Both the number of categories obtained and the proportion of perseverative errors reflect the age and number of education of the subject, even when the scores are controlled for general intellectual ability. However, the correlations between the measures on the MCST and the demographic variables are quite low. These results support those obtained by Parkin & Walter (1991) that ageing is accompanied by a decrease in the number of categories obtained, and an increase in the proportion of perseverative errors. Nelson (1976) also found a relationship between age and the number of categories completed, but did not find a relationship between age and the proportion of perseverative errors. The sample of healthy participants in the present study is larger and more heterogeneous than the sample in Nelson's original report, and these differences could account for the small differences in results between the two studies.

General intellectual ability, as measured by performance on the WAIS–R, is even more highly correlated with performance on the MCST than is age. It is more highly associated with the number of categories completed than with the proportion of perseverative errors. Similar results were reported by van den Broek *et al*. (1993). It is apparent from Figure 4 that there is a wider range of scores for the number of categories completed and the percentage of perseverative errors for individuals with an FSIQ below 100 than for individuals with an FSIQ above 100.

The association between performance on the MCST and general intellectual ability raises two issues. First, it appears that the WAIS–R measures some of the functions measured by the MCST. This relationship between a measure of general intellectual ability and performance on a test of executive function provides support for the proposal (Duncan, Emslie, Williams, Johnson & Freer, 1996) that the components of general intellectual ability are the very processes measured by tests of executive function. The results here demonstrate that the WAIS–R measures some of the executive functions necessary to successfully complete categories (conceptual ability), but is a less satisfactory measure of the processes associated with perseveration. Second, the results underline the usefulness of evaluating the performance on the MCST in the context of the person's age and current general intellectual ability. The data provided in this study will assist in the interpretation of a patient's or client's performance.

The study also demonstrates clearly that although performance on the MCST is sensitive to age, education and intellectual functioning, these variables do not in any way account for the full variance in the performance on this task. Further research on individual differences in the performance on this task will increase understanding of the components of the task, and of the variety of factors and possible deficits that could lead to an impaired performance on it.

Acknowledgements

The authors thank the Mental Health Foundation and the Department of Psychology at the University of Aberdeen for their generous financial support, various companies (Elf Oil, City of Aberdeen, Contract Services Division, Marks and Spencer plc) that allowed the participation of some of their employees, and the anonymous referees for their helpful comments.

References

Bondi, M. W., Monsch, A. U., Butters, N., Salmon, D. P. & Paulson, J. S. (1993). Utility of a modified version of the Wisconsin card sorting test in the detection of dementia of the Alzheimer type. *The Clinical Neuropsychologist*, **7**, 161–170.

Boone, K. B., Ghaffarian, S., Lesser, I. M., Hill-Gutierrez, E. & Berman, N. G. (1993). Wisconsin card sorting performance in healthy, older adults: Relationship to age, sex, education, and IQ. *Journal of Clinical Psychology*, **49**, 54–60.

Burgess, P. W. & Shallice, T. (1996). Bizarre responses, rule detection and frontal lobe lesions. *Cortex*, **32**, 241–260.

Chelune, G. L. & Baer, R. A. (1986). Developmental norms for the Wisconsin card sorting task. *Journal of Clinical and Experimental Neuropsychology*, **8**, 219–228.

de Zubicaray, G. & Ashton, R. (1996). Nelson's (1976) modified card sorting test: A review. *The Clinical Neuropsychologist*, **10**, 245–254.

Duncan, J., Emslie, H., Williams, P. I., Johnson, R. I. & Freer, C. (1996). Intelligence and the frontal lobe: The organisation of goal-directed behaviour. *Cognitive Psychology*, **30**, 257–303.

Fristoe, N. M., Salthouse, T. A. & Woodard, J. (1997). Examination of age-related deficits on the Wisconsin Card Sorting Test. *Neuropsychology*, **11**, 428–436.

Gotham, A., Brown, R. & Marsden, C. (1988). 'Frontal' cognitive function in patients with Parkinson's disease 'on' and 'off' Levodopa. *Brain*, **111**, 299–321.

Grant, D. A. & Berg, E. A. (1948). A behavioural analysis of degree of reinforcement and ease of shifting to new responses in a Weigl-type card sorting problem. *Journal of Experimental Psychology*, **38**, 404–411.

Greve, K. W. & Smith, M. C. (1991). A comparison of the Wisconsin Card Sorting Test with the Modified Card Sorting Test for use with older adults. *Gerontology and Geriatrics Education*, **11**, 57–65.
Heaton, R. K., Chelune, G. J., Talley, J. L., Kay, G. C. & Curtiss, G. (1993). *Wisconsin Card Sorting Test Manual*. Odessa, FL: Psychological Assessment Resources.
Joyce, E. & Robbins, T. (1991). Frontal lobe function in Korsakoff and non-Korsakoff alcoholics: Planning and spatial working memory. *Neuropsychologia*, **29**, 709–723.
Kendall, M. & Gibbons, J. D. (1990). *Rank correlation methods*. London: Edward Arnold.
Lezak, M. (1983). *Neuropsychological assessment*. New York: Oxford University Press.
Maghsoodloo, S. & Pallos, L. L. (1981). Asymptotic behaviour of Kendall's partial rank correlation coefficient and additional quantile estimates. *Journal of Statistical Computation and Simulation*, **13**, 41–48.
McCarthy, R. A. & Warrington, E. K. (1990). *Cognitive neuropsychology*. San Diego: Academic Press.
Milner, B. (1963). Effects of different brain lesions on card sorting: The role of the frontal lobes. *Archives of Neurology*, **9**, 100–110.
Nelson, H. (1976). A modified card sorting test sensitive to frontal lobe defects. *Cortex*, **12**, 313–324.
Office of Population Censuses and Surveys (1991). *Standard occupational classification*, Vol. 3, *Social classifications and coding methodology*. London: HMSO.
Paniak, C., Miller, H. B., Murphy, D., Patterson, L. & Keizer, J. (1996). Canadian developmental norms for 9 to 14 year-olds on the Wisconsin Card Sorting Test. *Canadian Journal of Rehabilitation*, **9**, 233–237.
Parkin, A. J. & Walter, B. M. (1991). Ageing, short-term memory, and frontal dysfunction. *Psychobiology*, **19**, 175–179.
Parkin, A. J. & Walter, B. M. (1992). Recollective experience, normal ageing, and frontal dysfunction. *Psychology and Aging*, **7**, 290–298.
Paus, T., Kalina, M., Patocková, L., Angerová, Y., Cerny, R., Mecir, P., Bauer, J. & Drabec, P. (1991). Medical vs. lateral frontal lobe lesions and differential impairment of central-gaze fixation maintenance in man. *Brain*, **114**, 2051–2067.
Rosselli, M. & Ardila, A. (1993). Developmental norms for the Wisconsin Card Sorting Test in 5- to 12-year-old children. *Clinical Neuropsychologist*, **7**, 145–154.
Salthouse, T. A., Fristoe, N. & Rhee, S. H. (1996). How localized are age-related effects on neuropsychological measures? *Neuropsychology*, **10**, 272–285.
Shoqeirat, M. A., Mayes, A., MacDonald, C., Meudell, P. & Pickering, A. (1990). Performance on tests sensitive to frontal lobe lesions by patients with organic amnesia: Leng & Parkin revisited. *British Journal of Clinical Psychology*, **29**, 401–408.
Stratta, P., Rossi, A., Mancini, F., Cupillari, M., Mattei, P. & Casacchia, M. (1993). Wisconsin card sorting test performance and educational level in schizophrenic and control samples. *Neuropsychiatry, Neuropsychology & Behavioural Neurology*, **6**, 149–153.
van dn Broek, M., Bradshaw, C. & Szabadi, E. (1993). Utility of the modified Wisconsin card sorting test in neuropsychological assessment. *British Journal of Clinical Psychology*, **32**, 333–343.
Van der Linden, M. & Bruyer, R. (1992). Memory disturbances and signs of frontal lobe dysfunction in 29 patients operated for an aneurysm of the anterior communicating artery. *Acta Neurologica Belgica*, **92**, 255–277.
Wechsler, D. (1981). *Manual for the Wechsler Adult Intelligence Scale – Revised*. New York: Psychological Corporation.

Received 20 January 1998; revised version received 29 July 1998