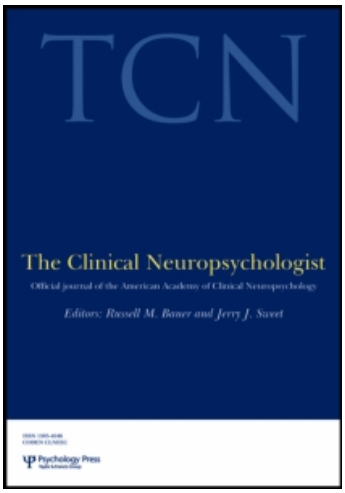

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EXPLORING AGE-RELATED DECLINE ON THE WISCONSIN CARD SORTING TEST

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It is well established that performance on the Wisconsin Card Sorting Test (WCST) tends to decline with advanced age, but the reason for this decline has not been established. The objective of the present study was to clarify this question using a qualitative approach to the task. The WCST was administered to 19 older adults and 25 younger participants. In addition to standard testing procedures, all participants were asked to verbalize their response strategy when placing each card. Results of this procedure implicate poor set shifting and set maintenance, consistent with reduced efficiency of feedback utilization, as the primary cause for age-related decline on the WCST.

INTRODUCTION

Since the publication of the Wisconsin Card Sorting Test (WCST), it has been well established that older adults display reduced performance on the test. A study was recently conducted by Axelrod and Henry (1992) to document these age-related changes. They found that aging beyond the fifties was associated with progressively decreasing performance on several variables: errors, perseverative errors, and perseverative responses. Many of the older adults in their sample, when compared with the WCST normative sample, performed at least as poorly as Heaton's (1981) nonfrontally lesioned patients. Additionally, Axelrod and Henry's (1992) adults over age 60 completed fewer categories than Heaton's (1981) younger adults (under 40). According to a more recent meta-analysis by Rhodes (2004), total number of perseverative errors is a slightly more sensitive variable to the effects of aging than categories completed.

The decrease in prefrontal volume seen with increasing age has been cited as a neuroanatomical explanation for this decline in performance, but the declines seen in older adults do differ from those seen in frontally lesioned patients. Older adults commit more total errors (whereas frontally lesioned patients primarily experience perseverative errors), and frontal lobe patients commit more perseverations to the previous sorting category (Hartman, Bolton, & Fehnel, 2001).

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A number of researchers have sought an etiological explanation for age-related changes on the WCST. Fristoe and colleagues (Fristoe, Salthouse, & Woodard, 1997) explored the use of a modified computer-based version of the WCST, in which participants were asked to select which hypothesis they were using for each response (color, form, or number). The results demonstrated that feedback usage had a significant impact on WCST results, but that this was mediated almost entirely by processing speed, which also impacts working memory. This suggested that rather than working memory being the cause of age-related decline on the WCST, it is simply a by-product of reduced processing speed, which directly impacts feedback usage and, thus, WCST performance. In this study, in being asked to choose the hypothesis they were using, the participants were informed of the various possible categories. This process alters the nature of the task, so that the performance on the WCST as a whole is not being evaluated through this procedure.

Ridderinkhof, Span, and van der Molen (2002) used two WCST-like tasks to determine the reason for the increased perseverative tendencies seen on the WCST with aging. The first experiment used a computer program displaying line drawings that were to be classified on one of three possible dimensions. One participant group was notified of a set shift, while another was not. Perseverative responses increased with age, but notification of set shift did not moderate the effect of age; the age-related difficulties therefore were concluded not to be related to the recognition of a shift in set, ruling out performance monitoring as the source of the age-related decline. The second WCST-like task was similar to the first, but included a condition in which the participant was given explicit set-shifting instructions (i.e., was notified of the target set). The explicit instructions were not found to improve performance, suggesting that hypothesis generation is not the problem, and that there is a fundamental set-shifting deficit in older adults.

Hartman et al. (2001) conducted a study to discern between two hypotheses of decline in WCST performance: working memory and cognitive flexibility. The authors proposed that the frequently reported increase in perseverative errors seen in older adults may reflect either cognitive inflexibility or working memory, and conducted a study to attempt to determine which is at play. Using new variables, it was concluded that perseverative errors occurring in older adults are not of the ''frontal'' perseveration type, and therefore should not be attributed to cognitive inflexibility. The new scores also indicated that working memory significantly influenced WCST results, suggesting that working memory, rather than cognitive inflexibility, played a primary role in age-related decline on the WCST. The study further suggested that this working memory deficit on the WCST is due to an inability to ''update'' working memory; relevant inputs (e.g., examiner feedback) are not adequately encoded for use on subsequent trials. To lend additional support to their findings regarding working memory, the authors created a ''cued'' modification for a second experiment by using cards that said ''yes'' after each correct response or ''no'' after each incorrect response. This modification actually remediated the performance of older adults to the point where there were no residual age differences in perseverative errors.

The purpose of the present study was to further explore and hopefully clarify the cognitive processes underlying age-related decline on the Wisconsin Card Sorting Test. Past research has examined the implementation of newly created scoring methods, modifications to the instructional set, and even modification of the test itself or

creation of similar tests, all with the goal of inferring the process by which older adults complete the WCST. Each of these previous studies, however, relied heavily on (1) inferences regarding the intentions of the participants, or (2) alterations to the task that changed the fundamental nature of the test itself. The present study aimed to resolve the question by administering the test in the traditional fashion, but asking the participants to verbalize their thought process for each response, in a manner similar to that used in Osmon and Suchy's (1996) Milwaukee Card Sorting Test. In this way, the cognitive processes at play can be qualitatively elucidated without altering or making inferences about the process.

Several possible causes of difficulty with the WCST can be explored using this approach:

1. *Cognitive inflexibility*, or the inability to identify all options and find a solution to the problem, would be implicated by difficulty with category recognition. This mechanism was proposed by Hartman and colleagues (2001) and Ridderinkhof and colleagues (2002), both of whom found this to be less likely than other hypotheses.
2. *Poor set shifting ability/perseveration*: As previously described, Ridderinkhof et al. (2002) found set-shifting impairment to be at the root of certain perseverative tendencies in older adults. Set-shifting behavior is an important component of the WCST, as participants must be able to shift set when required, but maintain set when a shift is not indicated. A high number of perseverative errors would suggest reduced set shifting and/or the influence of simple perseveration, while high failures to maintain set would implicate excessive shifting. The present modified approach can examine this more closely than the typical WCST scoring system, as the traditional scoring does not allow the examiner to interpret the participant's responses to ambiguous cards, which are plentiful in the WCST. The examiner often cannot determine whether the ambiguous responses represent set-maintenance or set-shifting efforts; with the verbalization of responses, this can be evaluated.
3. *Working memory/Processing speed*: Previous research has found both working memory and processing speed to be contributory, but Fristoe and colleagues (1997) found that the effect of working memory is mediated by processing speed. In the present study, it is possible that verbalization itself may help to remediate performance on the task, which could directly implicate working memory difficulties as the source of poor test performance in older adult populations. On the other hand, the verbalization requirement may increase working memory load beyond capacity, thus contributing to working memory induced reductions on the WCST.

METHOD

Participants

Two participant groups were recruited for the present study. The younger group consisted of 25 college students, ages 18–22 ($M = 19.79$, $SD = 1.37$). The older group was comprised of 19 adults, ages 63–89 ($M = 77.44$, $SD = 8.14$), with

no known neurological or psychiatric conditions, who were recruited through senior community centers.

Several potential participants were excluded from the study. One younger adult was excluded due to inability to perform the verbalization aspect of this WCST (due to a language barrier); four older adults were excluded on the basis of failing the screening tool (see below), and one terminated in the middle of the test due to hunger.

Materials

The Trail Making Test Parts A & B and the Wisconsin Card Sorting Test: Computer Version 4 (WCST; Heaton & PAR Staff, 2003) were administered to each participant.

Trail Making Test (TMT): The TMT is used here as a screening tool; participants who had extreme difficulty on the TMT Part B, defined here as falling below the 10th percentile on TMT B on the basis of previously established normative data (Tombaugh, 2004), were discontinued, as they would not be expected to be able to complete the more complicated WCST. This cutoff was set because the objective of this screening procedure was to reduce the likelihood of imposing undue frustration on a participant whose extreme executive difficulties would inhibit their ability to comprehend the WCST task.

Procedure

After obtaining informed consent, the TMT was administered to each participant. Those participants who were able to complete the TMT successfully were shown the computer and given the WCST. The standard instructional set for the WCST was provided, with one slight modification. In addition to the traditional instructions, the participants were asked to verbally state their reason or strategy for placing each card before making their choice. It was also emphasized that the computer's statement of "right" or "wrong" was in response to their choice of card placement, and not to the individual's verbalization regarding their strategy. This qualitative response was scored manually, while all other scores were obtained through the computer scoring program. The responses were coded by two raters to improve reliability. Based on pilot efforts and theoretical reasoning, the chosen qualitative response categories were as follows:

1. *Correct Response*: Responses that receive positive feedback. Also in this category are incorrect responses that are placed based on prior positive feedback; for example, a response made to form that is correct only because the card also matches color is often followed by another response to form; this second response is a "correct sort" because the individual is responding to positive feedback in the correct manner. Also, all consecutive responses to a category beyond completion of 10 cards in that category are "correct responses" until the first instance of negative feedback. For the most part, this response category is very similar to the standard WCST category of Trials Correct.
2. *Responding Against Previous Negative Feedback*: Matching to a category despite receiving previous negative feedback during the same set. This includes failures to

shift despite being told that the current strategy is incorrect (e.g., continuing to match to color despite a "Wrong" prompt from the computer), which implicate perseveration or a simple attention deficit, as well as sorting to a category despite *earlier* negative input, which could be suggestive of reduced working memory abilities.

3. *Responses to Other Incorrect Category*: Incorrect response, but not of a perseverative nature; the first match to an incorrect category within a set, or an "excusable" error.
4. *Random Responding*: Matches for which the participant indicates that he/she does not know where to place the card, and therefore places it randomly. Elevated scores on this variable would implicate cognitive inflexibility and/or simple confusion.
5. *Inconsistent Verbalization*: Responses for which the individual verbally indicates a match to a category but places it differently. High scores on this variable would implicate working memory impairment or simple confusion.
6. *Shift of Category Despite Positive Feedback*: Essentially Loss of Set, but without any minimum consecutive series requirement. Any verbalized response to a category other than one that had been positively reinforced on the previous card is classified as this type of response. Losses of set naturally reflect poor set maintenance. The traditional "loss of set" variable is necessarily dependent on longer series due to the presence of ambiguous cards; this new variable would capture more set losses due to the elimination of the series length requirement.
7. *Sorting to Multiple Categories*: Any response that cannot be coded as matching to one category due to the participant's verbalization of more than one category for a single card.
8. *Sorting to Nonexistent Category*: Matching to categories other than color, form, or number. For example, placing the cards on each pile in sequence without regard for the card's content. This would indicate that the individual is thinking about the task differently and not utilizing the three simple categories, implicating altered cognitive flexibility.

In addition to these variables, to help clarify the role of cognitive flexibility, the following additional "category recognition" variables were created:

1. *Trials to Color*: The number of incorrect responses required before the individual identifies "color" as a category. Trials on which another category is first identified are not counted against this variable.
2. *Trials to Form*: Likewise, the number of incorrect responses provided before identifying the "form" category.
3. *Trials to Number*: The number of incorrect responses provided before identifying the "number" category.

To explore for significant differences between older and younger groups on the newly created qualitative variables, these variables (not including "category recognition" variables) were first converted into ratio scores. This was done because the full set of 128 "cards" was not administered to all participants. After these ratios were created, *t*-tests were performed on each set of variables. A Holm-modified

Bonferroni correction (Jaccard, 1998) was used to control the family-wise error rate, given that multiple comparisons of related variables were conducted in this study.

RESULTS

The older and younger groups did not differ with respect to years of education. The distribution of men and women was also not significantly discrepant between groups.

No younger adults performed at a level on the TMT that would result in exclusion from the study (TMT A: $M = 25.83$ seconds, $SD = 8.57$, range = 13–48; TMT B: $M = 47.25$ seconds, $SD = 10.32$, range = 34–65). As mentioned previously, four older adults performed below the 10th percentile for their age range on TMT B based on norms provided by Tombaugh (2004), and were excluded as a result. The remaining participants in the older group had a TMT A mean = 49.56 seconds, $SD = 21.80$, range = 25–112, and TMT B mean = 150.33 seconds, $SD = 50.45$, range = 72–240.

Table 1 demonstrates that, as expected, the older individuals performed more poorly on the traditional WCST variables than younger individuals. The only exception was Trials Correct, as there was no significant difference between groups on this variable. However, this is attributable to the fact that the older adults required more trials in order to complete the task, and therefore had more opportunities for correct responses. To better clarify the potential influence of the broad age range within the older adults, age was correlated with the traditional WCST variables within this group. Significant correlations were found between age and trials to first category ($r = .604$, $p = .006$), perseverative responses ($r = .497$, $p = .030$), and perseverative errors ($r = .496$, $p = .031$). All other correlations between older adult age and WCST variables were nonsignificant at the $p < .05$ level.

Of the newly created variables, there are two response types that are more frequently seen in the younger group. The first is Correct Response, $t = 5.91$, $p < .001$, revealing that the younger group produced a correct response 83.5% of the time, while the older adults' responses were correct a mere 54.1% of the time. Sorting to Other Incorrect Category, i.e., matching based on a strategy that is

Table 1 Performance of older and younger adults on standard Wisconsin Card Sorting Test variables

Variable	Mean (*SD*) of younger group	Mean (*SD*) of older group	*t*	*p*
Total trials	88.24 (17.52)	124.26 (11.37)	−8.25	<.001*
Trials correct	69.40 (6.65)	71.16 (13.71)	−.52	.611
Errors	18.84 (12.40)	53.11 (18.08)	−7.46	<.001
Perseverative responses	9.08 (6.51)	31.16 (13.66)	−6.50	<.001*
Perseverative errors	9.00 (6.59)	27.42 (10.67)	−6.62	<.001*
Categories	5.80 (0.58)	2.79 (2.04)	6.24	<.001*
Trials to 1st category	17.20 (9.63)	32.58 (19.98)	−3.09	.005*
Failure to maintain set	0.28 (0.54)	1.68 (1.49)	−3.91	.001*
Learning to learn	1.75 (3.19)	−4.60 (6.67)	3.13	.008*

*$p < .05$, using a Holm-modified Bonferroni correction to control for type I error.

Table 2 Performance rates for older and younger adults on Wisconsin Card Sorting Test qualitative variables

Sort result	Mean (*SD*) of younger group (%)	Mean (*SD*) of older group (%)	*t*	*p*
Correct	83.5 (10.6)	54.1 (19.6)	5.91	<.001*
Responding against previous negative feedback	9.4 (9.3)	32.4 (16.0)	−5.60	<.001*
Responses to other incorrect category	3.6 (1.2)	2.3 (1.2)	3.53	.001*
Random responding	0.5 (1.4)	1.8 (4.3)	−1.26	.222
Inconsistent verbalization	0.7 (1.0)	3.7 (6.5)	−2.06	.054
Shift of category despite positive feedback	1.5 (2.3)	4.8 (3.0)	−4.15	<.001*
Multiple categories	0.8 (1.8)	0.3 (0.7)	1.27	.214
Sorting to nonexistent category	0.1 (0.5)	0.6 (0.9)	−1.91	.068

*$p < .05$, using a Holm-modified Bonferroni correction to control for type I error.

incorrect but not perseverative, occurred on 3.6% of responses in the younger group and 2.3% of responses in the older group, $t = 3.53$, $p = .001$.

Two response types were more frequently seen in the older adult group. Responses Against Previous Negative Feedback, which represent the typical characterization of perseverative responses, occurred 9.4% of the time in the college student sample and 32.4% of the time in older adults, $t = -5.60$, $p < .001$. Older adults were also three times more likely to Respond Against Positive Feedback, $t = -4.15$, $p < .001$. The mean rates of each of the newly created qualitative variables as they occurred in each participant group can be found in Table 2.

Of the category recognition variables, only color took longer for the older adult group to identify, $t = -2.93$, $p = .009$. While older adults required nearly twice as many trials to recognize number as a category than did the younger adult group, this difference was not statistically significant. Across groups, form was initially much more salient than the other categories, as it was the first category attempted by 21 of 25 younger adults and 17 of 19 older adults. See Table 3 for a summary of the findings with respect to these variables.

DISCUSSION

The present study was undertaken to help clarify the reason for the decline in performance on the Wisconsin Card Sorting Test (WCST) that is seen with increasing age. The available literature on the subject has implicated a variety of potential

Table 3 Performance rates for older and younger adults on category recognition variables of the Wisconsin Card Sorting Test

Category	Mean (*SD*) of younger group	Mean (*SD*) of older group	*t*	*p*
Color	1.60 (0.76)	6.26 (6.91)	−2.93	.009*
Form	1.32 (1.14)	1.05 (0.23)	1.14	.265
Number	4.28 (11.67)	8.26 (14.24)	−1.02	.314

*$p < .05$, using a Holm-modified Bonferroni correction to control for type I error.

underlying causes, including reduced processing speed and an inability to update working memory. This study sought to clarify the test-taker's strategy by asking the individual to verbalize the approach used for each card. These responses were coded into new, qualitative variables, and groups of younger and older adults were compared on these variables to identify the differences in strategy. Several possible hypotheses were delineated earlier. These included:

1. *Cognitive inflexibility*. This would be implied by poor performance on the category recognition variables. The only category with which the older adults had greater relative difficulty was color. This difference on only one category is difficult to explain, particularly since that category is eventually utilized by all individuals. It has been suggested that, since form and number on the first stimulus card both match the first key card, this may prime recognition of those categories. The older participants may have greater difficulty abandoning these more "obvious" form and number principles. This or any similar explanation supports the theory that older adults are *able* to identify the categories, and therefore argues against the cognitive inflexibility hypothesis.
2. *Poor set-shifting abilities*. Clearly, perseverative errors occurred more frequently among older individuals. However, the errors committed in this study cannot be solely attributed to a set-shifting reduction, as many set shifts were incorrectly made as well. It therefore appears that set shifting in the older adult sample was not heavily influenced by the given feedback, and was marked by unprompted shifts (losses of set) as well as failures to shift (perseverations).
3. *Working memory/processing speed*. Rhodes (2004) postulates that one or both of these factors is at the root of age-related decline on the WCST, particularly since research has found high correspondence between processing speed and WCST performance. The present study did not incorporate measures of processing speed because the correspondence has previously been established, and such an approach would not help to determine causation. One factor that argues against working memory/processing speed as the mechanism behind the differences found in this study is that individuals often verbally acknowledged the positive or negative feedback despite their failure to adjust responses based on it. Verbalization evidently did not result in improved scores, although even the performance of patients with schizophrenia is improved when strategy verbalization is utilized (Perry, Potterat, & Braff, 2001). However, the verbalization requirement could be confusing, so it also may have taxed older participants' working memory such that they did not respond appropriately. The working memory hypothesis therefore cannot be ruled out, although it seems less likely due to the expectations formed based on the aforementioned research with clinical populations.

Overall, the two response types that were found to be more frequent in older adults as compared with younger individuals are (1) responses to a category despite previous negative feedback given regarding that category, and (2) shifts in set despite receiving positive feedback for the decision made on the previous trial. This pattern is noteworthy because it demonstrates that the poorer performance seen with these individuals is attributable to reduced feedback utilization efficiency. The verbalizations provided often demonstrated that the participant understood that his/her

response was correct or incorrect, but the individual still did not alter the response pattern to accommodate this feedback. For example, following an incorrect response an individual sometimes repeated the negative feedback that had been provided to them, but still continued to match to the same, incorrect set. This is interpreted as poor utilization of feedback despite adequate processing of the information.

While reduced efficiency of feedback utilization, implicating a basic set-shifting impairment (similar to that found by Ridderinkhof et al., 2002), is therefore concluded to be the most likely mechanism for the poorer performance exhibited by older adults, the reason for this reduction is less clear based on the results of this study. It is possible that working memory or processing speed is the root cause of the inability to appropriately shift cognitive set. Additional qualitative research using these methods should be conducted in the future to further clarify this finding.

Earlier studies also suggested that older adults demonstrate poorer use of feedback information, and they further postulated that their findings were rooted in poorer working memory abilities. For example, Offenbach (1974) utilized a paradigm that offered choices among several dimensions. Participants would choose a response and then indicate which of eight hypotheses guided their choice, and would then be told whether their response was correct or incorrect. On this task, older adults were less likely than younger adults to base a hypothesis for any given trial on feedback from the prior trial.

Reduced utilization of feedback has also been noted in individuals with known frontal impairment, such as those who have suffered traumatic brain injuries (Lezak, 2004). Despite awareness that an erroneous response has been offered, such individuals do not correct it unless they are explicitly instructed. Functionally, this response style is associated with poor planning, as the individual does not utilize available knowledge and/or anticipate needed resources or actions.

Using the method described in this study, information was successfully obtained without making assumptions regarding the nature of a newly created factor. Such assumptions can hinder successful progress toward the answer to a research question. By implementing a simultaneous qualitative methodology, the need for additional presumptive variables is circumvented, apparently without altering the nature of the task.

The adaptation made to the traditional, computerized WCST in the present paradigm is not an entirely novel approach, as it incorporates aspects of a more dramatic modification made by Osmon and Suchy (1996) in creating the Milwaukee Card Sorting Test. Such information is potentially very valuable; as seen in this study, knowledge of the underlying thought processes can help to clarify the nature of some difficulties noted in an administration of the WCST. It is important to note that the adjustment was not developed for clinical use, and its utility has not been empirically investigated. Future research should explore the potential impact of the change in instructional set in order to determine the nature of any effect it has on working memory load and, thus, overall performance.

One confounding factor noted in this study is the age range used. While the younger adults were all of college age, the older sample featured a 26-year range. This likely increases the variance within the group, which in turn introduces the possibility that the pattern of performance may not be consistent across the entire sample, and therefore would be less interpretable. Future research may seek to

explore a more restricted range of ages, such as the 65- to 74-year-old individuals described by Rhodes (2004) as ''middle-old'' (p. 483). In addition, estimates of cognitive or intellectual ability would be more appropriate for the determination of equivalence between older and younger groups than educational attainment. A college student with 13 years of education often differs from an older adult with 13 years of education. A more appropriate simple measure might be a test of word-reading ability such as the Reading subtest of the Wide Range Achievement Test (Wilkinson, 1993), which can be used as a proxy for baseline quality of education (Manly, Jacobs, Touradji, Small, & Stern, 2002).

Overall, this study introduces a method to study the strategies used by older adults on the Wisconsin Card Sorting Test. While it does not rule out the contribution of working memory and/or processing speed to age-related decline on this measure, the results implicate feedback utilization inefficiency as the more proximate cause. Future research would benefit from further qualitative clarification of the cognitive processes and neurological substrates involved in the reduced feedback utilization efficiency seen in the present study. The approach used here, and the resultant findings, should contribute valuable information toward future research on the topic.

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