CLINICAL ISSUES

Modification of the Stroop Color Word Test Improves Differentiation between Patients with Mild Head Injury and Matched Controls

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ABSTRACT

Previous studies have indicated that patients with mild head injury have no specific deficits in selective attention as assessed with the Stroop Color Word Test. It has been reported that patients may be slower to name colors, but that they are not disproportionately slower on the subtask with color-word interference. The present study examined whether the performance of patients with mild head injury (MHI) was worse than that of nonconcussed controls on a modified Stroop interference subtask of increased complexity. Patients (n=44) were individually matched with controls for age, sex, and education. It was found that MHI patients were significantly slower on this modified subtask, whereas there was no significant difference between the two groups with the original interference subtask. The findings support the hypothesis that the cognitive disturbances of patients with mild head injury may be subtle and only demonstrable with very sensitive tests.

Patients with mild head injury (MHI) may complain of a number of postconcussive symptoms, including headache, fatigue, and cognitive problems (Lishman, 1988). There is circumstantial evidence that the cognitive difficulties are especially experienced when MHI patients have to perform different tasks under time pressure or stress. Evidence is accumulating to indicate that even mild to moderate head injury may produce subtle cognitive deficits. These deficits are not usually detected with traditional neuropsychological tests of intelligence or memory (McMillan & Glucksman, 1987), but can only be demonstrated with more sensitive techniques of information processing and attention (Hugenholtz, Stuss, Stethem, & Richard, 1988). Studies on attention and head injury have usually focused on patients with moderate to severe injuries, and results indicate that deficits in divided attention are clearly present, whereas studies on selective or sustained attention yield conflicting results (Van Zomeren & Brouwer, 1987).

The Stroop Color Word Test (Stroop, 1935) has been used to measure selective attention in patients with head injury (e.g., Van Zomeren & Brouwer, 1987). Although the Stroop Test has various forms, the essence of the test is that performance on several subtests is compared. The color-word interference subtask requires the subject to name a set of colors when they are printed as letters in a conflicting color (e.g., 'blue' printed in green ink). The performance of subjects on this subtask is compared with the performance on other subtasks in which the subjects read color words printed in black or in the appropriate colored ink. Stroop (1935) found that subjects take longer to perform on the color-word interference subtask than on the other two subtasks. Generally, the difference in time needed is thought to reflect interference of the automatic reading response with the response required by the task, and that this can be taken as a measure of selective attention (Dyer, 1973; Lowe & Mitterer, 1982).

So far, studies that have applied the Stroop Color Word Test to patients with head injuries have yielded consistent results indicating that subjects who are recovering from head injuries are slower than controls in both color naming and color naming with interference subtasks, but that they are not disproportionately slower in the interference task (e.g., Chadwick, Rutter, Brown, Shaffer, & Traub, 1981; Stuss et al., 1985, Thomas, 1977).

McLean, Temkin, Dikmen, and Wyler (1983) found that patients with moderate to severe head injury differed from controls on all three measures of the Stroop Test 3 days after their injury. No differences were found between the two groups 6 months after the injury, although the authors commented that the difference in the interference measure just failed to reach statistical significance. This tendency toward a difference between the two groups suggests that a subtle persistent deficit of selective attention, as revealed by performance on the Stroop Test, might be present in patients with head injury. It is possible that the standard Stroop Test is not sensitive enough to detect subtle changes in attentional performance after head injury. Moreover, the demands in terms of executive functions (Luria, 1966) in the Stroop Test are not very complex as the requirement of naming the colors of words is constant during the interference condition involving 100 words (Van Zomeren & Brouwer, 1987).

The aim of the present study was to test a newly developed subtask of the Stroop Test that makes more demands on subjects by requiring them to shift between color naming and word reading. We tested the hypothesis that patients about 10 days after a mild head injury would be slower than matched healthy controls in performing a modified subtask of complex color-word interference. The demands of the new subtask are greater than those of the orthodox color-
word interference subtask as flexibility is required for the naming and reading of the items depending on a special visual cue given with the words.

METHODS

Subjects
Patients were selected from a larger group of patients who were participants in a comprehensive cohort study of consecutively admitted patients with mild head injury. Mild head injury was defined as a concussion with a posttraumatic amnesia not exceeding 60 minutes, a period of unconsciousness of less than 15 minutes, and a Glasgow Coma Score of 15 on admission to hospital (see also Russell, 1971, and Rimel, Giordani, Barth, Ball, & Jane, 1981). In addition, the criteria for inclusion in the study included a posttraumatic interval of about 10 days (6-14 days), no serious traumatic physical complication (including the absence of an orthopaedic injury), and willingness to participate. Patients who were intoxicated at the time of the trauma or who had a skull fracture were also excluded. From a consecutive series of 158 patients, 44 patients fulfilled the above mentioned criteria of an uncomplicated MHI and were also in the age category between 15 and 43 years. None of the subjects was involved in litigation and none had a neuropsychiatric history. Patients were individually matched with healthy controls for age (± 4 years), sex, and educational level (± 1 level; Verhage, 1964) in order to control for possible biasing effects. All patients and controls were younger than 45 years. None of the subjects was color blind. The causes of the injury were traffic (32), falls (5), fights (1), sports (5), and accident at work (1); n=44. The matched control subjects (n=44) were selected from a pool of healthy nonconcealed volunteers. The mean age and educational levels of these subjects are presented in Table 1. All subjects gave their informed consent.

Test Material
Stroop Test. The Stroop Color Word Test used in the present study is a version available commercially in the Netherlands (Swets & Zeitlinger, Lisse, 1971). The test consists of three parts, each part being presented on a 21 x 29.5 cm sheet of paper. Ten lines are printed in each subtask with 10 items per line. The test utilizes the speed at which the names of a 100 color names (yellow, green, red, and blue) are read (Subtask I) and the speed at which 100 colored spots are named (Subtask II). Subtask III again involves 100 color names, but the naming of the printing ink of the words is taken as the test variable. The color-word interference score is obtained by subtraction of the time needed for Subtask II from that of Subtask III.

New Subtask IV. Twenty items from Subtask III were randomly selected, and small rectangles (0.8 x 2.0 cm) were drawn around these words (see figure 1). The instructions as given to subjects for the modified subtask (Subtask IV) were the same as those for Subtask III, except for the rectangularly lined items: For these items, the subject was requested to read the printed word. This condition was used to introduce additional interference as compared to the typical condition of naming the printing ink of the words rather than reading the names. Subtraction of the time needed for Subtask II (color naming) from that for Subtask IV (IV-II) was calculated as a measure of interference for Subtask IV. All subjects were instructed to perform the task as quickly and as accurately as possible. The two measures of interference for Subtask III (III-II) and Subtask IV (IV-II) were used as the cognitive parameters in the present study. One-tailed significance levels were applied corresponding to the unidirectional hypothesis.

Fig. 1. Modified subtask of the Stroop Color Word Test: 20 items are randomly placed within a rectangle.

Table 1. Means (SDs) for age and educational level (Verhage, 1964) of the patient and control groups.

<table>
<thead>
<tr>
<th></th>
<th>n</th>
<th>Age (yrs)</th>
<th>Educational Level (range 1-7)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patients</td>
<td>44</td>
<td>24.5 (8.9)</td>
<td>5.0 (0.9)</td>
</tr>
<tr>
<td>Controls</td>
<td>44</td>
<td>23.4 (8.1)</td>
<td>4.9 (0.8)</td>
</tr>
</tbody>
</table>

RESULTS

The results for the four subtasks of the Stroop Test are presented in Table 2. T tests (86 df) indicated that there was no significant difference between the patients and controls for the original interference score (III-II): 30.07 (11.10) and 28.73 (9.51), respectively; t = -.06 ns. In contrast, the interference score for the modified subtask (IV-II) was significantly different in patients and controls: 48.09
Table 2. Results of the Stroop Color Word Test. Means (SDs) in seconds.

<table>
<thead>
<tr>
<th>Subtask</th>
<th>MHI-patients</th>
<th>Controls</th>
</tr>
</thead>
<tbody>
<tr>
<td>(n=44)</td>
<td>(n=44)</td>
<td></td>
</tr>
<tr>
<td>I</td>
<td>43.22 (7.55)</td>
<td>41.94 (5.27)</td>
</tr>
<tr>
<td>II</td>
<td>57.96 (9.99)</td>
<td>54.54 (9.01)</td>
</tr>
<tr>
<td>III</td>
<td>88.03 (16.75)</td>
<td>87.28 (14.76)</td>
</tr>
<tr>
<td>IV</td>
<td>106.06 (22.84)</td>
<td>96.93 (13.51)</td>
</tr>
</tbody>
</table>

Interference Measures

| III-II  | 30.07 (11.10) | 28.73 (9.51) |
| IV-II   | 48.09 (16.69) | 42.39 (13.86) |

(16.69) and 42.39 (13.86), respectively; t = -1.73, p < .05 (one-tailed). This indicates that there was only a significant effect on the modified interference measure.

**DISCUSSION**

Studies in which the Stroop Color Word Test has been used with patients with head injuries have yielded consistent results indicating that the patients have no specific difficulty in focusing on the color dimension of the ambiguous stimuli (Chadwick et al., 1981; Stuss et al., 1985; Thomas, 1977). The results of the present study confirm this finding in patients with mild head injury, as assessed by the standard Stroop Color Word Test. Scores for the modified subtask of increased complexity, however, indicated that the patients with MHI were significantly slower than the controls. The extra mental flexibility and strategies needed in the modified subtask to direct attention to the different interference stimuli may have been responsible for this effect (see also Lowe & Mitterer, 1982).

The present findings support the hypothesis that the cognitive deficits in patients with MHI are subtle and that the orthodox color-word interference test may not be sensitive enough to detect differences between MHI and non-MHI subjects (McLean et al., 1983). That the modified subtask requires more effort is consistent with circumstantial evidence that MHI patients experience their cognitive shortcomings especially when they have to deal with complexity or have to perform under time pressure. The patients appear to be able to cope with the demands of everyday life only when no time pressure is demanded of them or when they are allowed to do one thing at a time at their own pace.

Notwithstanding the significant difference between the two groups, the variability among subjects was high: Statistical differentiation between groups does not imply individual prediction. It needs to be stressed that a postinjury interval of 10 days is quite brief. It is likely that the difference between the two groups may disappear at a more prolonged time postinjury. Nevertheless, it is clear that a number of patients recover quickly after MHI and do not have problems, whereas others recover slowly and have problems. This could imply that the present series of patients is heterogeneous and covers different subgroups of patients with varying degrees of posttraumatic brain dysfunction. It is possible that the test has extra value when applied to a subgroup of MHI patients with persistent subjective disability (see also Leininger, Grimaldi, Farrell, Kreutzer, & Peck, 1990). The significant difference between the patients and controls found in the present experiments may thus be an underestimation of the sensitivity of the test to detect a posttraumatic cognitive deficit.

Likewise, effects of age and education can be expected to play a role as well. Post hoc analysis indicated an even greater difference between more highly educated patients with MHI and matched controls: This is of interest as it indicates that the more difficult modified subtask 'tests the limits' of subjects for whom the regular Stroop tests are not difficult enough and, thus, rather insensitive. When adjusted for other factors, education may explain about one fourth of the total variance.

In summary, the present study provides evidence that subtle deficits in color word interference are demonstrable in patients with mild head injury only on a cognitively more demanding situation.

Further research is needed to investigate other factors, such as age and education, and to compare patients with and without postconcussive sequelae at more prolonged postinjury times to assess the sensitivity of the modified subtask for the detection of posttraumatic brain dysfunction.

**REFERENCES**


CLINICAL ISSUES

Free-Recall, Cued-Recall and Recognition Procedures with Three Verbal Memory Tests: Normative Data From Age 20 to 79

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ABSTRACT

New versions of three verbal learning tests (paragraph learning, list learning, and word-pair learning) were normed on 420 subjects, aged 20 to 79. These tasks used multiple acquisition trials, employed a delayed retention trial, incorporated the Buschke Selective Reminding procedure and utilized a continuum of free-recall, cued-recall, and recognition tasks. Norms are presented for six, 10-year age groups equated for intellectual level and gender. Normative groups also were screened for depression, dementia, and psychiatric illness. Results showed that all three tasks were highly reliable, demonstrated promising construct validity, and appeared to be measuring the same underlying cognitive function. Basic interpretative strategies for use with clinical data are proposed.

Historically, assessment of verbal memory has been dominated by three verbal learning paradigms. The first is passage or paragraph recall, as typified by the Logical Memory subscale of the original and revised Wechsler Memory Scale (WMS: Wechsler, 1945; WMS-R: Wechsler, 1987). The second method is list learning, or serial learning as it is sometimes called, which is exemplified by Rey's Auditory Verbal Learning Test (AVLT: Rey, 1964), the California Verbal Learning Test (CVLT; Delis, Kramer, Kaplan, & Ober, 1987), and the Buschke (1973, 1984) lists. The third method is paired-associate or word-pair learning, typified by the Associate Learning portion of the original and revised WMS and Inglis' (1959) Paired Associate Test.

This research was supported in part by grants from Natural Sciences and Engineering Research Council of Canada and Carleton University awarded to the second author. Correspondence should be addressed to James P. Schmidt, Suite 530, 220 Cambie Street, Vancouver, B.C., Canada V6B 2M9.

Accepted for publication: August 11, 1991.