AUTOMATIC DETECTION VS CONTROLLED SEARCH:
A PAPER-AND-PENCIL APPROACH

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Summary.—A new measure of selective attention was presented to 259 normal volunteers. The test was derived from earlier work which emphasized the importance of controlling the distracting conditions using a selective-attention paradigm. In the present study a paper-and-pencil, digit-cancellation format was introduced and the data documented a significant dissociation between tasks analogous to controlled search and automatic detection, two theoretically important aspects of selective attention. Presented is a discussion of similarities and differences of the new measure and classical methods of discriminating between controlled search and automatic detection and the potential significance of this discrimination in clinical neuropsychological investigations.

Psychomotor and vigilance tests are among the most sensitive measures to capture brain damage. Among such measures, cross-through tests have been successfully utilized to assess neuropsychological deficits following brain damage (7, 15). In these procedures, one or two targets are embedded among distractors, and the subject is instructed to scan rows of stimuli to select the randomly distributed targets by cancelling them as quickly as possible. Up to now, targets and distractors have typically been chosen from the same stimulus category. For example, in one of the tests the target d” has to be selected among other alphabetical letters with the same hyphen simply alternating in its spatial location ("d, p" etc.).

The present study introduces two types of distractor conditions, while relying on the same paper-and-pencil format. The reason behind introducing different distractor conditions was based on a large body of literature devoted to the study of selective attention (8, 11, 12, 13, 17). By utilizing primarily tachistoscopic presentations, these studies have demonstrated that a distinction can be made between using distractors from the same or different stimulus category. That is, if the targets and distractors are selected from the same stimulus category, then the reaction times are significantly slower compared to the condition in which a different stimulus category was introduced as distractors. In
a by now classical paradigm, the digits 2 and 7 represented the target stimuli, and distractors in one condition were other digits (same stimulus category), whereas in a second condition the distractors were alphabetical letters (different stimulus category). For the first mentioned condition, reaction times needed for correct identification were significantly longer when compared to the latter mentioned condition. Based on numerous investigations, Shiffrin and Schneider (12, 13), among others (8), have experimentally and theoretically dissociated between control search and automatic detection based primarily on the variation of distractor conditions. Not necessarily on a theoretical but rather practical level, it appears feasible to introduce two types of distractor conditions in a paper-and-pencil measure. For sake of simplicity, the terms control search and automatic detection are used to identify the two distractor conditions, although the differences between the present paradigm and the concepts implied in the selective attention literature will be addressed in the discussion.

The present study takes the first step towards developing a paper-and-pencil measure which allows dissociation between two types of distractor conditions. Using normal subjects, we assumed that there would be a significant difference between the cross-through rate of the two distractor conditions. Specifically, we proposed that the different distractor condition (digit-letter) would lead to significantly higher cross-through rates than the same distractor conditions (digit-digit). If such a discrimination could be achieved, this paper-and-pencil measure could then in further studies be administered to various patient populations suffering from neurological disorders. Note that a bedside measurement is needed to capture a wide variety of brain-impaired patients, and visual-field cuts as well as unilateral neglect can invalidate tachistoscopic presentations. Since the present study serves the purpose of exploring whether the proposed measure can be developed into a neuropsychological test measure, a large enough sample was evaluated to assess whether education, age, or sex played a role. Other than the expected decline of psychomotor speed with the increase in age, no further differences were postulated with respect to sex and education.

**METHOD**

**Subjects**

The total sample of 259 subjects included 152 women and 107 men. Approximately half of the sample resided in California, the rest in Michigan. With respect to age and education, the over-all sample was deliberately made heterogeneous. Young people aged 16 yr. formed the lower age limit and

*Control search corresponds to the condition in which the targets and distractors belong to the same stimulus category, i.e., digits among digits, whereas automatic detection refers to different stimulus categories for targets and distractors, i.e., digits among letters.*
elderly people of age 70 were the oldest. In addition, subjects were also chosen based on their educational attainment, from a low of 7 yr. to a high of 72 yr. schooling. Table 1 provides a breakdown of the stratifications according to age and education. The design called for representation of the various ages and years of education, and given the diversity of people in the total sample, independent subgroups were planned for and developed based on age and education simultaneously. There were two reasons for this: the first was to ensure relatively homogeneous subgroups for testing, and the second was to provide the opportunity to investigate performance differences among the age range and among those of greater and lesser educational achievement.

**Procedure**

Illustrated in Fig. 1 are two representative blocks of trials in which the subject was instructed to cross through Targets 2 and 7 as quickly as possible. In one block the targets are embedded in digits and in the other the distractors are capitalized alphabetical letters.

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**The 2 and 7 Test**

![Image of targets embedded in letters and digits]

**Fig. 1.** Sample blocks of targets embedded in either letters or digits
The subject was then asked to proceed through the sample (as illustrated in Fig. 1), and if errors were made the examiner would emphasize the need for accuracy. The subject was instructed to initiate the search from the top left side of the line and to proceed to the second and third lines in similar fashion. Following completion of the sample, the subject was instructed that in the main part of the test similar blocks would be presented in a column going down the page. The subject was told that, after a brief period of time, the examiner would say "Next", at which time the subject was to start a new block. Finally, performance speed was again emphasized.

In the main part of the test, a total time of 5 min. is given to work through 20 blocks (20 blocks X 15 sec. per block). The sequence of distractors is as follows (D = digits; L = letters): D, L, I, D, D, I, D, I, D, I, D, L, D, L, D, L, D. The test form is comprised of two 8½ X 11 in. pages taped together. The distance between all target items and distractor items is identical and equals approximately 3 mm. Each line contains a total of 50 characters which includes 10 target items and 40 distractor items. Target location is randomized throughout each line.

To score the test the number of correct detections was obtained within each of the 20 blocks. Omission errors were scored for all target items which were not identified preceding the last correctly identified target. Note that this score, total errors, is comprised of both omissions and commissions. The same criteria were applied for scoring both conditions where digit or letter distractors were employed. Finally, a performance curve was established by comparing the 10 consecutive blocks with either digit or letter distractors.

RESULTS

Sex Differences

Although there was no reason a priori to suppose that men and women would differ in the ability for each of the tasks, statistical analyses were performed to ensure that no sex differences existed. By partitioning the sample, there were 12 independent subgroups and for each of these a t test was conducted comparing men's and women's scores. These tests were separately calculated for both conditions of same and different distractors. Of these comparisons, only two reached significance (p < .05), and these two were attributed to sample differences. Scores for men and women were appropriately combined for the entire sample and for each subgroup of age and education.

Automatic Detection vs Controlled Search

Considering the entire sample of 259 subjects, numbers of targets cancelled between the two distractor conditions were analyzed using a one way analysis of variance. The mean number of targets crossed out for the automatic detection condition was 146.6, and for the controlled search 131.0 (F1,258
\[ \frac{256, p < .001, \Omega^2 = .50} \]. This is totally in accord with the hypothesized difference.

Because the sample is relatively large and contains the preselected subgroups, there is an advantage gained by finer analysis of smaller portions of the sample as well as of the whole. Following the convention of subdividing the total sample into 12 reasonably uniform subgroups based on four age groups and three levels of education, comparisons between automatic detection and controlled search were made for each of these subgroups. The mean cancellation rate of 2s and 7s for the conditions of automatic detection and for controlled search is illustrated in Table 2.

**TABLE 2**

**MEAN CANCELLATION SCORES AND STANDARD DEVIATIONS FOR CONDITIONS OF AUTOMATIC DETECTION AND FOR CONTROLLED SEARCH**

<table>
<thead>
<tr>
<th>Condition/Age (yr.)</th>
<th>(\leq 12)</th>
<th>(13-15)</th>
<th>(\geq 16)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(n)</td>
<td>(M)</td>
<td>(SD)</td>
</tr>
<tr>
<td><strong>Automatic Detection</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>16—24</td>
<td>32</td>
<td>148.9</td>
<td>29.8</td>
</tr>
<tr>
<td>25—39</td>
<td>26</td>
<td>142.8</td>
<td>27.1</td>
</tr>
<tr>
<td>40—54</td>
<td>18</td>
<td>131.7</td>
<td>26.9</td>
</tr>
<tr>
<td>55—70</td>
<td>14</td>
<td>124.7</td>
<td>21.8</td>
</tr>
<tr>
<td><strong>Controlled Search</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>16—24</td>
<td>32</td>
<td>134.2</td>
<td>24.6</td>
</tr>
<tr>
<td>25—39</td>
<td>26</td>
<td>126.4</td>
<td>24.9</td>
</tr>
<tr>
<td>40—54</td>
<td>18</td>
<td>119.2</td>
<td>19.5</td>
</tr>
<tr>
<td>55—70</td>
<td>14</td>
<td>113.7</td>
<td>18.4</td>
</tr>
</tbody>
</table>

*Note.*—Automatic detection scores are significantly higher than controlled search scores for all subgroups \(p < .001\).

For each subgroup a one-way analysis of variance was conducted comparing the two conditions. Inspection of Table 2 clearly demonstrates that significantly more targets were crossed out when targets were embedded in letters than digits. This finding holds true for each and every separate age and education subgroup. Although not presented in Table 2, \(\omega\) values were calculated for each comparison. This statistic by Keppel (6) represents the proportion of explained variance or strength of the association and is particularly useful when all comparisons between conditions differ as greatly as these do. The proportion of explained variance ranges from a low of 23% to a high of 69% and for most groups is about 50% or greater.

**Differences in Age and Education**

At every age and level of education more targets were cancelled when
embedded in letters than in digits. The question is then raised as to the effects of age and education for each condition taken separately. Does increasing age or more education influence scores for either controlled search or automatic detection? The experiment was designed to answer this because of the inclusion of the independent subgroups.

For each condition, the data were analyzed to examine the effects in increasing age and greater educational achievement using a two-way fixed-effects model of analysis of variance. The factor of age contains four levels, and the factor of education has three levels. The condition of controlled search documented that both age and education were significant, but interactions between age and education were negligible (Table 3). When the two-way analysis of variance was conducted for the automatic detection condition, identical results were obtained (Table 3).

With regard to age, a steady and linear decline in the rate of crossing out the targets in both conditions was observed with increasing age. With in-
creasing education, there was rise in cancellation rates, although the relation is linear only at lower levels of education, becoming asymptotic at about 15 yr. of education.

**Test/Retest Reliability**

A total of 99 subjects were retested after 6 mo. This interval was chosen because it corresponds to the typical duration occurring between follow-up evaluations for patients with neurological disorders, e.g., to document recovery from head injury or progression of dementia. For a comparison over time, the sample was stratified according to age only to obtain sufficient numbers per cell for meaningful computation. The correlations for that stratification are presented in Table 4. Note that in this second testing all groups demonstrated a consistent improvement of performance by approximately 10 points and, although the spread declines with an increase in age, the correlations remain consistently high, ranging from .84 to .97.

**Performance Curve**

Since the tachistoscopic research cited earlier yielded a practice effect for automatic detection but not for controlled search, the presently introduced task was analyzed according to performance curve. These curves were established by consecutively aligning the 10 blocks containing either letter or digit distractors. The curves are remarkably similar between the various subgroups. To illustrate this, Fig. 2 contains a comparison between the overall curve (with a grand total of 259 subjects) and one of the subgroups ($n = 30$, age 25—39 yr. with 13 to 15 yr. of education).

![Fig. 2. Curves on digits and letters for all subjects (N = 257) over 10 trials and those of one subgroup (n = 30, 25 to 39 yr. old with 13 to 15 yr. of education).](image-url)
the digit distractors, with the exception of the first set of blocks. The inverse pattern may be attributed to the fact that this particular digit task is the very first block on the test. Such a primacy effect might be expected during the first few trials prior to the individual's familiarization with the task. For all subsequent blocks the performance on the digit task drops below that of the letter task. Moreover, a convergence between the two tasks is observed about three quarters of the way through the test (see Trials 7 and 8 in Fig. 2). This is then followed by an end phase in which automatic detection again takes a strong lead.

**Discussion**

This newly introduced paper-and-pencil procedure captured a significant spread between the two distractor conditions. The assumption was confirmed that the digit-letter condition would result in a significantly higher hit rate compared to the digit-digit condition. With an increase in age there was a decline in the hit rate, but in all age groups there was a significant spread between the two distractor conditions. In addition, no sex differences were apparent, and the hit rate of those subjects with up to high school education was significantly below that of the two groups with college education. Although the performance curves had a number of distinguishing characteristics, practice did not provide a significant difference between the two distractor conditions. Finally, the paper-and-pencil measure proved reliable over time.

A series of studies are needed prior to linking the present paper-and-pencil measure to the rich literature of selective attention. This is due to a number of salient differences between the tachistoscopic paradigms and the introduced paper-and-pencil measure. First, in the tachistoscopic presentation the tasks are *discrete*; in the cross-through tests *sustained* attention is required since the targets have to be continuously selected within the 5 min. it takes to complete the tests. The second difference which is introduced in the paper-and-pencil measure is its reliance on graphomotoric skills. Tachistoscopic paradigms typically rely upon verbal response or reaction time, whereas in the cross-through test fine motor movements are required. A third distinguishing feature is the difference in visual processing, i.e., attending to the visual field while fixating on a central point in the tachistoscope vs visually scanning the rows for target selection. Despite these differences, the findings are remarkably consistent, since the digit-digit condition led to significantly inferior performances when compared to the digit-letter conditions.

Since the impetus for developing a paper-and-pencil measure was based on its neuropsychological application (3), a number of advantages will be discussed. As mentioned earlier, cross-through tests have been effectively utilized in neuropsychology. In fact, psychomotor tests such as the digit symbol of the WAIS—R are among the most sensitive measures developed to docu-
ment underlying neuropathology (2, 9). To evaluate patient populations with neurological disorders, there are the mentioned visual advantages, and the fact is that this is a bedside method. By combining the two distractor conditions with a task of sustained attention, this method holds the promise of being sensitive for capturing performance deficits resulting from organic dysfunction.

A series of projects are already underway which were prompted by the present study. In one of these projects the norming will be completed with adults as well as children. This presently introduced measure has been selected as part of the neuropsychological test battery of the National Head Injury Data Bank (a multicenter project funded by the National Institutes of Health). In addition, this measure is being administered to a variety of patients with neurological and psychopathologies. In testing these patient populations, motor movements need to be assessed. In our test using 20 blocks there was no decline in performance over time, and it is expected if motor slowing should occur in clinical populations that it would equally affect both conditions. This assumption, however, needs to be assessed in future studies which contrast this measure with other measures of motor, visuomotor, and psychomotor tasks. It is noteworthy that a dissociation between same and different distractors was also found in a study of monkeys in which event-related potentials were measured concurrently (1). Despite rather drastic alterations concerning the presentation modes for the same and different distractors, it appears that the differentiation between them is robust.

REFERENCES


8. MADDEN, D. J. Age differences and similarities in the improvement of controlled search. Experimental Aging Research, 1982, 8, 91-98.


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