Adaptive and Maladaptive Utilization of Color Cues by Patients With Mild to Moderate Alzheimer’s Disease

Stacey Wood
University of Houston

Karl F. Mortel
Veterans Administration Medical Center, Houston

Merrill Hiscock, Bruno G. Breitmeyer, and Jerome S. Caroselli
University of Houston

The ability to utilize color information was investigated in 12 patients with mild to moderate probable Alzheimer’s Disease (DAT) and in 12 age- and gender-matched control subjects. All subjects underwent testing of visual acuity and color vision before being tested with a cognitive task consisting of four conditions (no color, color as attention enhancer, color as valid cue, color as distracter). Although the groups did not differ in visual acuity or color vision, patients with DAT were less accurate than controls in all four conditions of the cognitive task. Both groups performed best with color as a valid cue and worst with color as distracter, but condition had a significantly stronger effect on patients than on controls. It is concluded that color is a potent stimulus attribute for patients with DAT. © 1997 National Academy of Neuropsychology. Published by Elsevier Science Ltd

Disturbance of visuospatial functions is a prominent symptom of patients with mild to moderate dementia of the Alzheimer’s type, or DAT (Cummings & Benson, 1983; Joynt & Shoulson, 1985; Mendez, Mendez, Martin, Smythe, & Whitehouse, 1990a). Although some visuospatial problems may be attributed to memory loss, recent research has identified visual system abnormalities—for example, loss of contrast sensitivity, loss of depth perception, and increased latency of visual evoked potentials—that may be associated with impaired visuospatial functioning (Cogan & Lesell, 1985; Cronin-Golomb, Corkin, Rizzo, Cohen, Growden, & Banks, 1991). Other visual functions, such as color vision and visual acuity,
appear to remain relatively spared (Cogan & Lesell, 1985; Cronin-Golomb et al., 1991; Kiyoshawa et al., 1989; Mendez, Tomsak, & Remler, 1990b).

One explanation for this pattern of visuospatial functioning in DAT is based on the existence of anatomically distinct magnocellular and parvocellular subsystems (Mishkin, Ungerleider, & Macko, 1983). Perhaps because it has an affinity for larger neurons (Terry & Katzman, 1983), DAT may infiltrate the magnocellular system first, leaving parvocellular functions, such as form discrimination and color vision, relatively intact (Kosslyn, Flynn, Amsterdam, & Wang, 1990).

The primary purpose of our study was to determine the degree to which color influences patients with DAT as they attempt to solve a simple cognitive task. If color can be shown to be a salient stimulus attribute for patients with DAT, then it may be possible to use color effectively in their management.

METHOD

Subjects

Twelve normal volunteers and 12 patients with a diagnosis of DAT participated in the study. Each group consisted of five men and seven women. Patients with DAT were recruited from the Cerebral Blood Flow Laboratory of the Veterans Affairs Medical Center/Baylor College of Medicine, Houston, TX, where they were participating in a longitudinal study of normal aging and dementia. Patients were mildly to moderately demented as determined by the Mini-Mental State Examination (MMSE; Folstein, Folstein, & McHugh, 1975) and were living at home. The neurologically and cognitively normal controls were friends or relatives of the patients.

DAT was diagnosed by a staff neurologist using criteria set by the National Institute of Neurological and Communicative Diseases (NINCDS; 1984) and the Alzheimer's Disease and Related Disorders Association (ADRDA; 1984). These criteria are compatible with the Diagnostic and Statistical Manual-III-R (DSM-III-R; American Psychiatric Association, 1987) and the International Classification of Diseases (McKhann et al., 1984). Criteria for exclusion included:

1. A severity of dementia that would render the subject untestable;
2. Dementia other than DAT;
3. History of serious psychiatric disorder;
4. Modified Hachinski Index greater than 6 (Rosen, Terry, Fuld, Katzman, & Peck, 1980);
5. History of stroke or cerebrovascular disease;

Table 1 shows the mean age and educational level for each group. Neither difference was statistically significant by t test, p > 0.15. The mean MMSE score was 13.3 for the DAT group. Scores ranged from 7 to 25, placing the patients in the mild to moderately impaired range. The mean MMSE score for the control group was 29.3. Scores ranged from 27 to 30, placing these subjects in the normal range. All subjects were able to comprehend instructions and to perform each task.

Procedure

All testing was accomplished during a single 2-hour session. In addition, the MMSE and a clinical interview were administered to determine the severity of dementia.
TABLE 1
Subject Demographics and Results of Visual Acuity and Color Vision Tests

<table>
<thead>
<tr>
<th>Group</th>
<th>DAT</th>
<th>Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Males</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Number of Females</td>
<td>7</td>
<td>7</td>
</tr>
<tr>
<td>Age in Years</td>
<td>76.7 (4.1)\textsuperscript{a}</td>
<td>73.5 (6.1)</td>
</tr>
<tr>
<td>Education Level in Years</td>
<td>11.6 (5.2)</td>
<td>13.9 (4.6)</td>
</tr>
<tr>
<td>Visual Acuity\textsuperscript{a}</td>
<td>35.0 (10.4)</td>
<td>32.9 (8.9)</td>
</tr>
<tr>
<td>Red-Green Color Vision</td>
<td>14.5 (0.9)</td>
<td>14.8 (0.5)</td>
</tr>
<tr>
<td>Yellow-Blue Color Vision</td>
<td>3.8 (0.5)</td>
<td>3.8 (0.4)</td>
</tr>
</tbody>
</table>

\textsuperscript{a}Values in parentheses are SDs.

Visual acuity. A standard Clark acuity card was used to test for best corrected near vision to a maximum of 20/20. The right eye (left occluded) was tested first, then the left eye (right occluded), and then both eyes together. The remaining procedures were accomplished with corrected vision.

Color vision testing. Illumination was standardized using a Tektronics J16 digital photometer to approximate overcast daytime sunlight or standard illuminate C, which is recommended for color vision testing (Archibald, 1987). Ishikawa (Ishikawa, Hukami, Tannabbe, & Kawakami, 1978) plate 1, which does not require intact color vision, was administered first to alert the examiner to possible anomia or confusion. Ishihara (1987) plates 1–15 were used to test for red/green color defects. Ishihara plates 17 and 18 and Ishikawa plates 2 and 3 were used to test for blue/yellow color defects.

Cognitive testing. A task requiring pattern recognition and analogical reasoning was administered under four conditions. Condition 1 (no color) consisted of set A (items 1–12) from Raven’s Standard Progressive Matrices (Raven, 1977). Condition 2 (color as attention enhancer) consisted of set A (items 1–12) from Raven’s Coloured Matrices (Raven, 1971). Items were identical to those in the first condition except that the patterns and response alternatives were colored uniformly. In Condition 3 (color as valid cue), each item from Set A of the Standard Progressive Matrices was modified by coloring the correct response and one other to match the standard. This enabled the subject to eliminate four incorrect responses on the basis of a color mismatch. In Condition 4 (color as distracter), two incorrect responses for each item of the Standard Progressive Matrices were colored to match the standard, thereby inducing the subject to make an incorrect response on the basis of a color match.

The 48 items were presented in a randomized order. Prior to testing, two practice items from the no color and cue conditions, respectively, were administered to ensure that the subject understood the task. Each presentation began with the subject being reminded to match the pattern regardless of color. Then the stimulus array was shown and the subject was asked to point to the correct response out of six possible responses. Response time for each item was recorded and rounded to the nearest second, with a time limit of 60 seconds per item.
RESULTS

Visual Acuity and Color Vision

Means and SD are shown in Table 1. There was no significant difference between groups in visual acuity, $t < 1$, which indicates that visual acuity was adequate to perform the remainder of the tasks and that differences in performance on later tasks were not attributable to visual acuity.

There was no significant difference between groups in either red-green or yellow-blue color vision, $t < 1$. All individuals within both groups performed within normal limits. There was no significant gender difference on either measure, $p > 0.20$.

Cognitive Tasks

Accuracy. Correct responses were analyzed using a $2 \times 4$ mixed factorial analysis of variance (ANOVA) with group as a between-subjects factor, and condition (no color, color, cue, distracter) as a repeated-measures factor. The condition effect and Group $\times$ Condition interaction were decomposed into three specific contrasts: (a) no color versus color, to determine whether the addition of a uniform color would change performance; (b) color versus cue, to determine whether valid color cues would be more beneficial than uniform color; and (c) color versus distracter, to determine if performance would decrease when color was used to distract attention from the target item.

A significant main effect for group, $F(1, 22) = 11.69, p < 0.01$, indicates that control subjects outscored DAT subjects. The condition effect was also significant, $F(3, 66) = 34.64, p < 0.001$. These findings are depicted in Figure 1.

The contrast between no color and color conditions was not significant, $F < 1$, nor did this contrast interact significantly with group, $F < 1$. Although performance in the cue condition was superior to performance in the color condition, $F(1, 22) = 16.96, p < 0.001$, this contrast did not interact significantly with group. Accuracy was lower in the distracter condition than in the color condition, $F(1, 22) = 57.68, p < 0.001$. A significant Group $\times$ Color versus Distracter interaction, $F(1, 22) = 4.61, p < 0.05$, indicated that DAT patients were significantly more impaired by the distracter than were control subjects.
Utilization of Color in Alzheimer's

Response Time

FIGURE 2. Mean response latency in seconds for DAT and control groups across the four experimental conditions: Condition 1: no color; Condition 2: color as attention enhancer; Condition 3: color as valid cue; Condition 4: color as distracter.

Response time. Latency data were analyzed in the same way as correct response data. Although the main effect for group was not significant, there was a significant condition effect, $F(3, 66) = 8.00, p < 0.001$, and a significant Group $\times$ Condition interaction. $F(3, 66) = 7.57, p < 0.01$. The means are shown in Figure 2.

Neither the no color versus color contrast, $F < 1$, nor the Group $\times$ No Color versus Color interaction was significant, $F < 1$. Responses were significantly faster in the cue condition than in the color condition, $F(1, 22) = 30.08, p < 0.001$, and a significant Group $\times$ Color versus Cue Condition interaction, $F(1, 22) = 7.57, p < 0.025$, indicated that the improvement associated with valid cues was greater for patients than for controls. Response times in the distracter condition were significantly longer than in the color condition, $F(1, 22) = 5.12, p < 0.05$, but this contrast did not interact significantly with group, $F < 1$.

Correlation between response accuracy and time. A Kendall rank correlation (Siegel, 1956) was calculated for each group and within each condition to determine whether there were significant tradeoffs between accuracy and response time. For control subjects, coefficients of 0.03, 0.30, 0.50, and 0.45 were obtained for conditions 1–4, respectively. Correlations for DAT patients were 0.29, 0.63, 0.33, and 0.09, respectively. Positive correlations are consistent with a speed-accuracy tradeoff. In the conditions of particular interest, that is, cue and distracter, controls showed a statistically significant tradeoff but patients did not.

Gender differences. Supplemental ANOVAs revealed no significant gender differences for either accuracy or response time, nor did gender interact significantly with group or condition.

DISCUSSION

The negative findings for visual acuity, red-green color vision, and yellow-blue color vision are consistent with previous evidence that parvocellular functions are relatively intact in patients with DAT (Mendez et al., 1990a). Nonetheless, because the color plates provide only a rudimentary measure of color vision, one cannot conclude that patients with DAT are entirely normal in their processing of color information (Kosslyn et al., 1990). In addition,
subtle deficits might have been missed because of the low statistical power associated with small samples.

Results for the cognitive task indicate that patients with DAT responded to the manipulation of color information much as controls did. When differences between groups were found, patients were more strongly influenced by color than were controls. Response times decreased more markedly in patients than in controls when color cues were helpful, and accuracy decreased more dramatically in patients than in controls when color cues were detrimental. These findings indicate not only that patients with DAT are capable of utilizing color information but also that they find color cues especially salient. The tendency to be “pulled” by misleading color cues could be construed as a concrete response style, which is often indicative of impaired “executive functioning” and attributable to frontal lobe dysfunction (Lezak, 1983). A concrete response style is common among patients with DAT (Katzman & Saitoh, 1991).

Overall, the accuracy measure was more sensitive to interference than to facilitation, whereas response time was more sensitive to facilitation than to interference. Perhaps this is why differences between the groups in color-related facilitation were manifested in response time whereas group differences in interference were manifested in accuracy. The stronger overall effect—that of interference on accuracy and of facilitation on speed—may have provided a greater range in which the performance of the two groups could diverge.

Our findings do not necessitate the conclusion that color is a more effective cue than another stimulus attribute or that the efficacy of color cues is limited to patients with DAT. Perhaps similar adaptive and maladaptive effects could be duplicated with another salient stimulus attribute, such as size or contrast, and perhaps similar effects could be demonstrated in other low-functioning populations. Nonetheless, the results do show that patients with DAT are able to use color cues adaptively when the cues are helpful and that patients are especially susceptible to being misled by invalid color cues.

In addition to the disadvantage of modest statistical power, the present study is limited by the heterogeneity of MMSE scores for patients and by the substantial—though statistically nonsignificant—difference between groups in educational level. The findings consequently should be regarded as tentative until replicated in a larger sample of patients. Accordingly, the practical implications must be verified empirically, the main implication being that the early-stage DAT patient may benefit from the addition of color coding to traditional memory aids such as memory notebooks, schedules, and errand lists. Institutionalized patients might benefit from having doors and corridors painted in distinctive colors and from having care-givers wear clothing of different colors. Additional research is needed to determine whether color coding can facilitate the learning of new information, the degree to which color-aided learning is maintained over time and the rate at which the usefulness of color cues diminishes as dementia progresses.

REFERENCES


