Freehand drawing impairments in probable Alzheimer’s disease

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Abstract
We evaluated freehand picture production of familiar objects in patients with probable Alzheimer’s disease. The overall recognizability of their drawings was significantly compromised. Error analyses revealed the production of category violations and the frequent inclusion of incorrect features in a picture that were borrowed from semantically related objects, suggesting difficulty distinguishing between items with overlapping feature sets in semantic memory. Analyses of individual patient drawing profiles also revealed that some patients are disproportionately compromised in expressing a particular perceptual feature, implicating difficulty at the level of perceptual processing. Regression analyses demonstrated the contribution of limited visual attentional resources. We conclude that impaired freehand drawing in probable Alzheimer’s disease is multifactorial in nature.

(KEYWORDS: Alzheimer’s disease, Picture, Cognition, Visual)

INTRODUCTION
Difficulty drawing a spontaneous picture had been reported frequently in early clinical descriptions of probable Alzheimer’s disease (pAD) (Sjögren et al., 1952; Ajuriaguerra et al., 1960). More detailed analyses have confirmed these early observations (Moore & Wyke, 1984; Sunderland et al., 1989; Wolf-Klein et al., 1989; Brantjes & Bouma, 1991; Kirk & Kertesz, 1991; Rouleau et al., 1992), although the basis for this drawing difficulty remains to be established. The purpose of this study was to examine freehand drawing deficits in pAD more systematically.

Several models of picture production have been proposed that can help assess freehand drawing difficulty in pAD (Roncato et al., 1987; van Sommers, 1989; Grossman, 1993; Mickanin et al., 1994). A highly simplified description includes a component that identifies a pre-visual, conceptual representation of the appropriate information corresponding to the target picture in semantic memory. An abstract perceptual description is derived from the conceptual representation that includes shape and color features and a structural frame that organizes these features. These abstract mental features adopt specific visuo-perceptuo-spatial values in a visual output buffer during picture realization. The visual output buffer holds an evolving mental description of the target picture during production, so that emerging properties of the picture can be accommodated to the remainder of the drawing environment. The output buffer is updated continuously on the basis of visual perceptual feedback from the actual production, and this information is validated against the abstract perceptual description and the associated conceptual representation.

Alzheimer’s disease is a heterogeneous disorder that can result in freehand drawing impairments for several different reasons. In the present study, we monitored the extent to which drawing difficulty in pAD was related to compromised processing of the conceptual representation in semantic memory, and to impaired processing of specific perceptual features, such as shape and color, during creation of the perceptual description and picture realization. Many studies thus have claimed that pAD patients are impaired in the processing of information represented mentally in semantic memory (Huff et al., 1986; Martin, 1987; Chertkow et al., 1992; Hodges et al., 1992; Chan et al., 1993), including difficulty processing picture meaning (Chertkow & Bub, 1990; Grossman & Mickanin, 1994; Rouleau et al., 1992). Earlier stud-
ies of drawing had associated the semantic memory deficit in pAD with the compromised expression of a picture's details (Grober et al., 1985; Flicker et al., 1987). Simplification of drawings has been observed frequently in pAD (Moore & Wyke, 1984; Brantjes & Bouma, 1991; Kirk & Kertesz, 1991; Ober et al., 1991), but such a nonspecific finding can be attributed to an impairment at many different levels of picture processing.

In the present study, we sought to identify a type of drawing error that reflects more specifically a semantic memory deficit. In particular, we performed qualitative analyses of picture production errors to identify how often an incorrect feature was borrowed from an object that overlaps semantically with the intended target, such as a leaf incorporated in a mushroom picture. This was compared with the production of incorrect picture features borrowed from semantically unrelated objects, such as the head of a hammer included in a picture of an apple. This analysis was motivated by the finding that pAD patients with semantic memory difficulty are impaired at judging the category membership of anomalous pictures that contain features from objects that are semantically related, although they are accurate at judging the category membership of pictures containing anomalous features borrowed from semantically unrelated objects (Grossman & Mckainan, 1994).

This study also demonstrated that pAD patients are impaired in their category membership judgments of pictures and words. They accepted semantically related foils that overlap in many features as exemplars of the target concept (also cf. Huff et al., 1986; Flicker et al., 1987; Martin, 1987; Chertkow & Bub, 1990; Chertkow et al., 1992; Chan et al., 1993), and produced semantically related category violations in their semantically guided category naming fluency (Mckainan et al., 1994). In the present report, then, we also evaluated the frequency of category drawing violations that are related semantically to the target, such as producing a carrot when asked to draw pictures of fruit, and category violations that are semantically unrelated, such as a chair in response to a request for fruit.

Another source of freehand drawing difficulty may be the compromised processing of specific perceptual features such as color or shape. There is some evidence that the appreciation of shape may be impaired in pAD (Nissen et al., 1985; Sadun et al., 1987; Shuttleworth & Huber 1989; Mendez et al., 1990), and several studies have attributed the poor recognizability of clock and house drawings in part to difficulty expressing shape (Moore & Wyke, 1984; Wolf-Klein et al., 1989; Brantjes & Bouma, 1991; Kirk & Kertesz, 1991; Rouleau et al., 1992). Similarly, color processing may be compromised in pAD (Risser et al., 1990; Cronin-Golomb et al., 1991), although we are not aware that this has been examined in pAD patients' picture production. In the present study, we monitored the production of specific shape, color, and relative size attributes in pAD patients' freehand drawings. We distinguished between a semantically based deficit and a perceptually based deficit in pAD patients' picture production errors by assessing the quality and nature of the drawings with which the error was associated. Thus, unlike a semantic error, a perceptually based error was a semantically unrelated attribute such as a square-shaped apple. Moreover, perceptual features such as shape and color appear to be represented in specific brain regions that can be selectively compromised in individual patients (Gross, 1973; Ungerleider & Mishkin, 1982; Desimone et al., 1985; Zeki et al., 1991; Grady et al., 1992; Sergent et al., 1992). Thus, a consistent deficit restricted to a particular type of perceptual feature in an individual patient would suggest difficulty processing perceptual information.

Freehand drawing difficulty may also be due in part to an impairment producing a picture's features in a fashion that is organized by a structural frame (Grossman & Carvell, 1993). It has been claimed that pAD patients are disorganized in their constructions of objects such as a clock face (Brantjes & Bouma, 1991; Ober et al., 1991; Rouleau et al., 1992). It is not often possible to predict in an a priori fashion the structural organization of a freehand picture, but one indication can come from an assessment of the distribution of the picture's details (Moore & Wyke, 1984; Ober et al., 1991). For example, a stem emerging from the enlarged portion of a pear body may be an error due to the poor organization of the picture. In the present study, we analyzed the frequency that the organizational distribution of details was compromised in pAD.

The model of freehand drawing outlined above includes the contribution of short-term memory, selective attention, and feedback sensory perceptual components in the production of a recognizable picture. We administered a brief battery of visual neuropsychological tasks to assess these elements. Correlation and regression analyses were used to relate performance on these tasks to the recognizability of freehand drawings in pAD.

Taken together, we hypothesized that pAD patients as a group would produce less recognizable freehand pictures than age-matched controls. Analyses of group-wide and individual patient performance profiles were expected to indicate several sources of impairment in pAD, including a semantic memory deficit and difficulty producing well-organized perceptual attributes such as shape and color. We expected these deficits to be related to limitations in the distribution of attentional resources and sensory perceptual processing.

METHODS

Research Participants

We studied 19 right-handed, high school-educated, native English speakers (9 males, 10 females) with probable dementia of the Alzheimer's type, according to NINCDS-ADRDA criteria (McKhann et al., 1984). All patients were thought to be mildly or moderately impaired according to the clinical evaluation, and scores on the Mini Mental State examination (Polstein et al., 1975) were greater than 12. Clinical and demographic factors are summarized in Table 1. We excluded from consideration patients with evidence for other progressive neurodegenerative conditions such as
Parkinson's disease, patients with other dementing conditions such as vascular dementia (Hachinski ischemia scores [Rosen et al., 1980] were 2 or less), patients with a history or diagnosis of a primary psychiatric disorder such as major depression or schizophrenia, patients with a history or diagnosis of other neurological diseases such as stroke or hydrocephalus, patients taking centrally active medications such as neuroleptics or antidepressants, and patients with any metabolic or systemic disorder that might have affected their intellectual functioning. Clinical assessment indicated that the patients were not color-blind.

As summarized in Table 1, pAD patients were compared with 20 age-matched [t(38) = 1.66; NS] control subjects. The control subjects were somewhat better educated than the pAD patients [t(37) = 4.76; p < .001]. Analyses of covariance and correlational analyses reported in the Results section demonstrated that differences in age could not fully explain the discrepancies in drawing performance that we observed.

Materials

The subjects were asked to perform a freehand semantic category drawing task. They were given eight colored felt pens and asked to produce as many instances of a target category in a freehand fashion as they could in 3 min. We used familiar organic and man-made superordinate terms for the target domains—"fruits" and "tools." Superordinate targets were used so that we could monitor pAD patients' production of semantic category violations. Patients were reminded to attend to the shape, color, and relative size of their pictures, and to draw the pictures carefully so that others could recognize them. The name of the patient's picture was determined with a recognition naming procedure, where the examiner provided three alternative names.

A standardized scoring procedure was used to evaluate the pictures (Grossman, 1988, 1993). Briefly, we counted the number of responses that patients produced for each category during the 3-min period. We assigned a representativeness score between 1.00 and 7.00 to each item (Rosch, 1975). Items that were not on tables listing instances of the target domain (Battig & Montague, 1969; Rosch, 1975) were considered to be category violations, and disputed items were checked in dictionaries. We noted the number and nature of these category membership violations. To score the recognizability of each drawing, we evaluated the shapes, relative sizes, and associated details of the fruit and tool pictures that were produced. Specifically, we used independent criteria based on dictionary definitions to evaluate the accuracy of a picture's characteristics, and assigned a score on a 16-point scale to quantify a picture's overall recognizability. Shape was scored by assigning 4 points for the correct shape, 2 points for a shape of a related item that was not the correct shape for the particular exemplar (e.g., a pear-shaped apple), and no points for an incorrect and unrelated shape (e.g., a square apple). We considered a feature to be unrelated if it violated the larger, natural kind or man-made nature of the target category. Each fruit picture was scored for color, assigning 4 points for the correct color and no points for an incorrect color. Tools were not scored for color since tools do not exhibit a necessary color. We also noted whether multiple colors were used to produce one picture of a fruit or a tool. We scored relative size within the set of instances produced for a target by assigning 4 points for the correct relative size and no points for an incorrect relative size (e.g., a hammer smaller than a nail). The details associated with a drawing were assigned 4 points, and were specifically scored 1 point each for the correct shape, color (only for fruit, and prorated for tools), size, and location of a detail. Detail location accuracy was determined on the basis of relative placement compared to other features. An overall recognizability score was obtained for each drawing by summing these points. Mean picture recognizability for a superordinate was the mean of the recognizability scores associated with the exemplars of this category. Because tools were not scored for color, we prorated the overall recognizability score for tools, and converted overall recognizability for both fruit and tools to a 100-point scale. Two independent raters, blinded to the hypotheses of the study, evaluated all of the pictures for recognizability. Inter-rater agreement for recognizability was 88.3% across the entire set of pictures. Differences were resolved through a consensus discussion.

In addition to freehand drawing, we administered several other tasks to help us evaluate specific aspects of picture production:

**Perceptual Matching**

To evaluate shape perception, subjects judged whether pairs of geometric designs taken from a standard set of graded geometric figures (Beery & Buktenica, 1967) are the same or different shape. Half of the pairs differed by one line.

**Visual Scanning**

The appropriate production of a picture's details may require the distribution of attentional resources in space. Sub-
jects were asked to identify 40 triangles from an array of 200 similarly sized geometric shapes (Weintraub & Mesulam, 1985). The triangles were equally distributed in the four spatial quadrants of the array.

**Pointing Span**

To assess visual short-term memory, subjects replicated a pointing sequence that had been demonstrated by the examiner immediately prior to production (Wechsler, 1987). The assigned score was derived from the failure to reproduce a sequence of a particular length on two consecutive trials.

**Rey-Osterrieth Figure Recall**

To help us assess the role of long-term memory in pAD patients' drawings, subjects were asked to copy this complex geometric design and then recall it 5 min later. The copy and the recall were scored on a standard 36-point scale (Lczak, 1983) where 2 points were assigned for the correct reproduction of each of 18 specific components of the design, 1 point was assigned if the component was reproduced in a partially correct fashion, and no points were assigned if the component was eliminated or extremely distorted spatially and perceptually. The other neuropsychological tasks were performed during the period between presentation and recall. Note that only 17 pAD patients and 16 controls were asked to copy and recall the Rey-Osterrieth figure.

These tasks were administered in a quiet testing room. The entire procedure required approximately 30 min. The subjects appeared to understand all of the tasks.

**RESULTS**

**Overall Picture Recognizability**

Some examples of pAD patients' freehand drawings are provided in Figure 1. An analysis of variance (ANOVA) compared the overall mean (±SD) recognizability of the pictures produced by pAD patients (68.79 ± 8.66) and control subjects (87.50 ± 7.45). This revealed a significant difference between groups \[ F(1,37) = 52.48; p < .0001 \]. Because education differed for the two groups, we reanalyzed overall picture recognizability covarying for education. A significant difference between groups was again found \[ F(1,36) = 26.85; p < .001 \], demonstrating that educational differences could not fully account for discrepancies in the recognizability of patients' drawings. We also correlated recognizability with clinical and demographic features such as dementia severity, but failed to find any significant correlations (Table 1).

Another possible explanation for differences in overall drawing recognizability is that patients quickly produced less recognizable pictures to increase the number of drawings produced. Indeed, pAD patients (3.79 ± 1.55) differed from control subjects (8.82 ± 2.34) in the mean (±SD) number of pictures that they produced during the allotted time \[ F(1,36) = 62.06; p < .0001 \]. An ANCOVA covarying recognizability for the number of pictures produced revealed a significant difference between groups \[ F(1,36) = 11.95; p < .01 \], indicating that impaired fluency performance could not fully explain discrepancies in freehand picture recognizability. We also examined the relative overall recognizability of freehand pictures of fruit compared to tools. We failed to find a significant difference in the recognizability of pictures produced within these two semantic domains \[ t(17) = 1.30; NS \]. These findings confirm impairments in overall freehand drawing recognizability in pAD, and indicate that these deficits are difficult to attribute entirely to factors such as educational differences, overall dementia severity, or compromised drawing fluency.

To determine whether group differences in drawing recognizability are also evident in the performance of individual patients, we converted pAD patients' performance to standard z-scores on the basis of control subjects' performance. Control subjects' performance was normally distributed \( W = 0.96; NS \), as was the performance of pAD patients \( W = 0.98; NS \). It may be noted that a z-score of \(-1.65\) differs from control subjects' performance at the \( p < .05 \) level, a z-score of \(-1.96\) differs from control subjects' performance at the \( p < .025 \) level, and a z-score of \(-2.32\) differs from control subjects' performance at the \( p < .01 \) level. Table 2 sum-

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**Fig. 1. Examples of pAD patients' freehand drawings of fruits and tools. 1 = Apple (drawn in red); 2 = knife; 3 = pear (drawn in green); 4 = screwdriver; 5 = screwdriver; 6 = banana (drawn in orange); 7 = banana (drawn in yellow); 8 = screwdriver.**

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Table 2. Individual pAD patient drawing profiles

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The data in this table refer to standard z-scores based on control subjects' performance. We selected a z-score of -1.96, equivalent to a \( p < .025 \) level of significance, as our cutoff for impaired drawing production.

Most freehand drawing scores refer to combined assessments of fruits and tools. However, the z-scores for color refer only to fruits since color is not a necessary property of a particular tool.

Semantic Factors in Picture Recognizability

We confirmed that pAD patients' pictures are simplified in comparison to controls' pictures since the pAD patients omitted significantly more details from their drawings \( r(37) = 3.80; p < .001 \). More importantly, we assessed the particular types of errors that pAD patients made during the drawings. As summarized in Figure 2, we found that pAD patients produce a significantly larger proportion of shape errors related to the target than controls \( r(38) = 2.97; p < .005 \), but do not differ from controls in the production of unrelated shape errors \( r(38) = 1.13; \) NS. Relatedly, pAD patients made significantly more shape errors that were related to the target superordinate than shape errors unrelated to the target \( r(17) = 3.71; p < .01 \). pAD patients thus were more likely to draw a banana that was pear-shaped than a square banana. This was equally evident in their drawings of fruit and tools \( r(18) = .079; \) NS.

We also assessed the frequency and nature of category violations in pAD patients' freehand drawings. Semanti-
Drawing impairments and Alzheimer’s disease

Preliminarily related category violations (e.g., drawing a carrot as a type of fruit) occurred in 15.0% of pAD patients’ pictures, but was seen only in 6.8% of controls’ pictures. All of the pAD patients’ category violations were related to the target category. These findings suggest that freehand drawing difficulty may be related in part to compromised processing of the mental representation of the information underlying a pictured object in semantic memory.

Perceptual Factors in Picture Recognizability

pAD patients’ ability to include accurate shape, color, relative size, and detail characteristics in their pictures is summarized in Figure 3. Using the criterion defined above to identify perceptual errors, we found that pAD patients are significantly less able to express several of these characteristics in their freehand pictures when compared to control subjects, including shape \( r(37) = 3.36; p < .002 \) and color \( r(37) = 4.49; p < .0001 \). We co-varied these comparisons for fluency, but the discrepancy in fluency could not fully account for differences in shape \( F(1,36) = 5.67; p < .02 \) or color \( F(1,36) = 8.36; p < .007 \). pAD patients were also significantly less likely than control subjects to produce pictures containing two colors \( r(37) = 4.18; p < .0005 \). Relative size was expressed with equal accuracy by pAD patients and control subjects \( r(37) = 0.67; \text{NS} \). Assessment of detail production confirmed that pAD patients are significantly impaired at expressing a set of perceptual attributes of a picture contributed to the overall recognizability of freehand drawings. We found that shape \( r(17) = 0.586; p < .05 \) but not color \( r(17) = 0.484; \text{NS} \) or relative size \( r(17) = -0.351; \text{NS} \) correlated with overall freehand drawing recognizability. The details’ shape \( r(17) = 0.816; p < .001 \), color \( r(17) = 0.637; p < .01 \), relative size \( r(17) = 0.797; p < .001 \), and location \( r(17) = 0.768; p < .001 \) correlated with overall picture recognizability. Intercorrelations for these perceptual features are provided in Table 3.

One critical issue with regard to perceptual processing is the nature of perceptual errors in individual pAD patients. Group-wide averaging could reflect that all patients are somewhat impaired at expressing all perceptual features, or that subsets of patients are impaired at expressing different types of perceptual features. Individual patient profiles for these perceptual characteristics are summarized in Table 2. Twelve (63.2%) of 19 pAD patients expressed perceptual attributes in a manner that was commensurate with the overall recognizability score of their pictures. For example, patients producing pictures with poor overall recognizability scores were equally impaired at expressing color, shape, and detail attributes. Exceptional drawing patterns are summarized in Table 2. Three of the remaining seven patients were impaired at producing shape attributes, five of these seven patients had difficulty producing color attributes, and three of these patients were impaired at producing details in their pictures. Some pAD patients thus appear to have a deficit expressing specific perceptual attributes.

We performed correlation analyses to determine the extent to which accuracy in producing the individual perceptual attributes of a picture contributed to the overall recognizability of fruits and tools. We used separate regression analyses for fruit and tool domains since color is only an attribute of fruits but not tools. A regression analysis using the overall recognizability of fruit as the dependent measure revealed a significant set of factors contributing to the recognizability of fruit pictures \( F(6,12) = 598.27 \). These factors accounted for 47.6% of the overall variance in the recognizability of fruit pictures. We found that the color \( r^2 = 0.339 \), shape \( r^2 = 0.038 \), relative size \( r^2 = 0.023 \), size of the detail \( r^2 = 0.042 \), the color of the detail \( r^2 = 0.031 \), the shape of the detail \( r^2 = 0.006 \) contributed to this regression formula. When we examined the factors contributing to the recognizability of tools, we found a significant regression formula as well \( F(3,15) = 100.97 \), explaining 95.3% of the overall variance in the recognizability of tools. This analysis revealed that shape \( r^2 = 19.47 \), relative size \( r^2 = 15.89 \), and the shape of the details \( r^2 = 59.92 \) contributed significantly to the recognizability of tools. Thus, specific perceptual attributes appear to contribute to the recognizability of freehand drawings in pAD.

A stepwise linear regression analysis (Dixon, 1988) was used to determine that relative contribution of these perceptual attributes to the recognizability of fruits and tools. We used separate regression analyses for fruit and tool domains since color is only an attribute of fruits but not tools. A regression analysis using the overall recognizability of fruit as the dependent measure revealed a significant set of factors contributing to the recognizability of fruit pictures \( F(6,12) = 598.27 \). These factors accounted for 47.6% of the overall variance in the recognizability of fruit pictures. We found that the color \( r^2 = 0.339 \), shape \( r^2 = 0.038 \), relative size \( r^2 = 0.023 \), size of the detail \( r^2 = 0.042 \), the color of the detail \( r^2 = 0.031 \), the shape of the detail \( r^2 = 0.006 \) contributed to this regression formula. When we examined the factors contributing to the recognizability of tools, we found a significant regression formula as well \( F(3,15) = 100.97 \), explaining 95.3% of the overall variance in the recognizability of tools. This analysis revealed that shape \( r^2 = 19.47 \), relative size \( r^2 = 15.89 \), and the shape of the details \( r^2 = 59.92 \) contributed significantly to the recognizability of tools. Thus, specific perceptual attributes appear to contribute to the recognizability of freehand drawings in pAD.

Structural Information and Other Aspects of Picture Recognizability

pAD patients were significantly impaired at expressing a detail’s location \( r(37) = 4.35; p < .0002 \), suggesting difficulty organizing a picture’s attributes.
Table 3. Intercorrelations of perceptual features in Alzheimer patients' freehand drawings

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<tr>
<td>Detail color</td>
<td>0.125</td>
<td>0.138</td>
<td>0.061</td>
<td>0.516</td>
<td>0.579</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Detail shape</td>
<td>0.339</td>
<td>0.468</td>
<td>0.481</td>
<td>0.831</td>
<td>0.641</td>
<td>0.966</td>
<td>0.983</td>
<td>—</td>
</tr>
<tr>
<td>Detail size</td>
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<td>0.426</td>
<td>0.455</td>
<td>0.764</td>
<td>0.604</td>
<td>0.983</td>
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</tr>
<tr>
<td>Detail location</td>
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<td>0.432</td>
<td>0.525</td>
<td>0.864</td>
<td>0.604</td>
<td>0.983</td>
<td>0.938</td>
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</tr>
</tbody>
</table>

*The Bonferroni technique was used to protect against type B errors during the multiple comparisons used in this table. For 28 comparisons, the threshold for significance must exceed 0.05/28, or p < .001. All but one of the most significant correlations were among the details, and only the correlations among details surpassed the threshold for significance.

pAD patients' performance on other visual neuropsychological measures is summarized in Figure 4. It can be seen that perceptual judgments of shape, pointing span, visual search, and visual memory all differed significantly from control subjects' performance at least at the p < .025 level. We sought to determine whether performance on any of these neuropsychological measures correlated with freehand picture recognizability. Only performance on visual scanning correlated significantly with freehand picture recognizability [r(17) = 0.706; p < .01]. We also performed an ANCOVA evaluating freehand drawing recognizability that covaried for the ability to copy the Rey figure. We found that drawing recognizability remained significantly impaired in pAD patients, despite taking into account the geometric design copy [F(1,30) = 13.30; p < .01]. This emphasizes the somewhat distinct nature of freehand drawing and copying a geometric design.

We used a stepwise linear regression analysis (Dixon, 1988) to determine the relative contribution of performance on these neuropsychological tasks to freehand picture recognizability. Independent variables included Rey figure copy, perceptual judgments, visual attention span, visual scanning, and visual memory. The regression algorithm identified a set of factors that contributed significantly to freehand drawing recognizability [F(2,15 = 13.29]. This formula accounted for 64% of the overall variance in pAD patients' freehand drawing. Visual scanning accounted for the bulk of the variance in the regression analysis (r² = 0.511), whereas shape judgments made a smaller contribution (r² = 0.128). This suggests a role for the distribution of visual attention and the appreciation of shape in pAD patients' freehand drawings.

DISCUSSION

These findings indicate that freehand drawing deficits are very common in pAD. The patients erred by expressing anomalous features in their pictures that were borrowed from semantically related concepts, and they produced category violations that depleted semantically related concepts. Individual patient analyses revealed that some patients are relatively impaired in the expression of particular types of perceptual attributes. Patients also had difficulty with the organized distribution of details, and visual scanning deficits were related to freehand drawing recognizability as well. We argue below that this indicates a multifactorial pattern of drawing difficulty in pAD.

Earlier reports of freehand drawing in pAD have illustrated compromised pictorial expression in these patients (Moore & Wyke, 1984; Sunderland et al., 1989; Wolf-Klein et al., 1989; Brantjes & Bouma, 1991; Kirk & Kertesz, 1991; Rouleau et al., 1992). We sought to clarify the basis for this difficulty. A frequent explanation offered to account for drawing deficits in pAD is that they have a "constructional
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apraxia” (Cummings & Benson, 1992). This may be operationalized in the present context as difficulty using a pen to draw a shape. Constructional apraxia is a vague clinical term that clearly cannot account for findings such as a deficit at expressing color. The omission of details has been attributed to a constructional apraxia, but the simplification or omission of features from a picture is nonspecific at best. An omission error is uninterpretable since it can be due to any of several levels of impairment, including degraded semantic knowledge or difficulty expressing a particular type of perceptual feature. We attempted to focus our analyses on the nature of the errors that are actually produced. For example, we analyzed errors such as expressing a shape borrowed from a semantically related object, producing the incorrect value of a color, and placing a detail in an incorrect position. Constructional apraxia cannot fully account for qualitatively distinct patterns of errors such as these.

Our analysis of picture recognizability in pAD was motivated by models of freehand drawing (Roncato et al., 1987; van Sommers, 1989; Grossman, 1993; Mickanin et al., 1994). pAD patients are said to have an impairment processing semantic memory (Grober et al., 1985; Huff et al., 1986; Flicker et al., 1987; Martin, 1987; Chertkow & Bub, 1990; Hodges et al., 1992). Such a semantic deficit could interfere with freehand drawing, according to our model, and thus could explain some of the difficulty these patients encountered in producing recognizable pictures. Evidence to support compromised semantic memory in pAD has been derived from studies of confrontation naming errors and recognition naming difficulties, where patients confuse items from the same superordinate category (Huff et al., 1986; Martin, 1987; Chertkow & Bub, 1990; Hodges et al., 1992). This hypothesis has been confirmed by studies assessing pAD patients’ category membership judgments of pictures. For example, Grossman and Mickanin (1994) asked pAD patients to judge the category membership of pictures and words, where half of the pictures were anomalous. The patients misjudged pictures where the anomalous feature was semantically related to the target picture, but were accurate at judging pictures where the anomalous feature was semantically unrelated to the target picture. In the present study, qualitative analysis of pAD patients’ errors revealed that they did not express a randomly incorrect shape when misdrawing a banana, but often produced a semantically related shape substitution such as a pear-shaped banana. Thus, evidence from freehand picture production resembles the observations from measures of picture recognition in pAD that suggest a deficit at a level of processing concerned with the meaning of a picture’s underlying concept.

pAD patients with a semantic memory deficit were also expected to produce category membership violations. Fifteen percent of their errors violated the semantic limitations of the category. All of these category violations were related semantically to the target superordinate, and pAD patients never produced a semantically unrelated category violation. The small number of category violations may be due to the fact that, on a spontaneous production task, patients may have chosen to produce only items they were convinced were category exemplars. In the context of this potential to optimize their performance, it is significant that pAD patients produced any category membership violations at all. The violations we observed were consistent with the claim that pAD patients have a semantic memory impairment that interferes with their ability to discriminate between concepts overlapping in many semantic features.

Several investigators have argued that there are differences in the mental representation of natural kinds compared to man-made artifacts that can result in category-specific differences naming objects (Schreuder et al., 1984; Flores D’Arcais & Schreuder, 1987; Vitkovitch et al., 1993). pAD patients are also said to have a category-specific impairment naming and recognizing items taken from an organic category, although they are less impaired in their performance with man-made items (Silveri et al., 1991; Mauri et al., 1994; Montanes et al., 1995). It has been argued further that relative difficulty with natural kinds is due in part to an impairment processing the visual attributes that are said to be critical for the mental representation of these items compared to man-made artifacts (Warrington & Shallice, 1984; Shallice, 1988). This account would have been expected to result in relative difficulty producing fruit pictures compared to tool pictures, but this was not observed. A recent study of speeded confrontation naming in pAD using carefully controlled stimuli (Tippett et al., in press) failed to support these category-specific claims in pAD, and a recent study of category naming has failed to find a difference in the quantity or quality of organic and man-made names that are produced (Mickanin et al., 1994). Moreover, regression analyses in the present study demonstrated that different sets of perceptual features contributed to the recognizability of fruits and tools. The precise status of the organic–man-made distinction in pAD remains to be established.

Importantly, freehand drawing difficulty in pAD cannot be attributed entirely to impaired processing of semantic memory. Investigators have noted visual perceptual difficulties in pAD that range from mild deficits appreciating shape and color to profound visual agnosias (Nissen et al., 1985; Sadun et al., 1987; Shuttleworth & Huber, 1989; Fisher et al., 1990; Mendez et al., 1990; Cronin-Golomb et al., 1991). Visual perceptual features such as color and shape are dissociable (Gross, 1973; Ungerleider & Mishkin, 1982; Desimone et al., 1985; Zeki et al., 1991; Grady et al., 1992; Sergent et al., 1992), and we observed that some patients have selective difficulty expressing some perceptual features but not others. This type of information is often difficult to ascertain in group-wide analyses, but we had the opportunity to identify these impairments since we examined individual patient profiles. Despite our attempt to identify distinct patterns of freehand drawing errors, it should be emphasized that the interpretation of an error as semantic or perceptual is difficult. Additional work is needed to confirm these distinctions using other approaches.

We also found evidence to support the claim that expression of information in an organized fashion may be difficult
for pAD patients. Thus, they were impaired in their ability to localize a detail in a picture (Moore & Wyke, 1984; Ober et al., 1991). There are several reasons to believe that this is not due to difficulty appreciating spatial relations. For example, relative size was expressed fairly accurately in pAD patients’ pictures. Relatedly, visual scanning was associated with poor drawing recognizability. Other reports have demonstrated that the distribution of visual attentional resources is compromised in pAD (Parasuraman et al., 1992), and that this deficit contributes to their difficulty on measures of naming and design processing (Massman et al., 1993; Kempler et al., 1995). pAD patients thus may be impaired in the organized distribution of attentional resources in space, and this may have contributed to the poor organization of detailed features.

Several caveats must be kept in mind when interpreting our findings. These patients were evaluated at a specialized university clinic, and there may have been some unintentional bias in patient or control subject selection. We evaluated patients who were mildly or moderately impaired, and our findings can be generalized only to this segment of the pAD population. Only two semantic categories were assessed over a limited period, and this constrained our perspective on the types of errors that patients could produce. Moreover, more detailed studies are needed to evaluate the expression of specific visual properties such as color and shape. We identified a role for the distribution of visual attentional resources and for shape perception in pAD patients’ picture recognizability, and our findings suggested little role for episodic memory; however, additional work is needed to evaluate the contribution of these and other factors in freehand picture production. The regression analyses must be viewed with caution because of the low subject-to-variable ratio. With these caveats in mind, we conclude that freehand drawing difficulty in pAD is multifactorial in nature. Deficits processing information in semantic memory and difficulty expressing particular, well-organized perceptual features, together with limitations in the distribution of attentional resources, appear to contribute to impoverished freehand picture recognizability in pAD.

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REFERENCES


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