Visual Discrimination Predicts Naming and Semantic Association Accuracy in Alzheimer Disease

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Objective: Language impairment is a common symptom of Alzheimer disease (AD), and is thought to be related to semantic processing. This study examines the contribution of another process, namely visual perception, on measures of confrontation naming and semantic association abilities in persons with probable AD.

Methods: Twenty individuals with probable mild-moderate Alzheimer disease and 20 age-matched controls completed a battery of neuropsychologic measures assessing visual perception, naming, and semantic association ability. Visual discrimination tasks that varied in the degree to which they likely accessed stored structural representations were used to gauge whether structural processing deficits could account for deficits in naming and in semantic association in AD.

Results: Visual discrimination abilities of nameable objects in AD strongly predicted performance on both picture naming and semantic association ability, but lacked the same predictive value for controls. Although impaired, performance on visual discrimination tests of abstract shapes and novel faces showed no significant relationship with picture naming and semantic association. These results provide additional evidence to support that structural processing deficits exist in AD, and may contribute to object recognition and naming deficits.

Conclusions: Our findings suggest that there is a common deficit in discrimination of pictures using nameable objects, picture naming, and semantic association of pictures in AD. Disturbances in structural processing of pictured items may be associated with lexical-semantic impairment in AD, owing to degraded internal storage of structural knowledge.

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Alzheimer disease (AD) represents the most common form of dementia in industrialized nations, currently affecting more than 5 million people in the United States, alone.[1] Communicative disorders are among the most functionally debilitating aspects of AD.[2,3] Yet, the development of principled language interventions for AD is hindered by a lack of consensus regarding the primary cause of the associated naming impairment. Although our most common behavioral association with AD is that of impaired episodic memory, it has long been recognized that language disturbances (ie, anomia) and visual perceptual impairments (ie, apperceptive agnosia) are also reliable markers of AD.[4] Patients with AD tend to experience inexorable worsening of naming impairment as the disease progresses, the basis for which remains controversial. One theoretic position holds that core knowledge of word and object meaning is relatively intact in early AD, but that patients experience deficits in lexical and/or conceptual retrieval.[5,6] An alternate position holds that anomia reflects loss of core semantic knowledge.[7,8] Although much of this debate has focused on access versus storage accounts of anomia, comparatively little research has focused on the moderating influence of visual object recognition deficits. We do so here by investigating the degree to which presemantic visual processing deficits predict picture naming and semantic association abilities on common diagnostic neuropsychologic measures.

ALZHEIMER DISEASE: PATHOLOGY AND CORTICAL VISUAL PROCESSING

Visual perceptual disturbances often precede the classic episodic memory impairments in AD.[9–11] The specific locus of impairment within the visual processing system remains unclear.[12] Initially, disturbances were attributed to higher level perceptual processing, as opposed to sensory deficits that impact global visual attributes, such as line orientation or form. This conclusion of perceptual over sensory impairment is supported by studies showing relatively intact visual acuity in AD, as gauged by perceptual matching and various other visual discrimination tasks (eg, shape detection, shape discrimination, size discrimination, hue discrimination,

and dot counting).[13] The hypothesis of associative, or higher-level perceptual processing deficits in AD, also receives converging anatomic support from postmortem investigations showing that the primary visual cortex remains intact relative to more anterior visual association areas (ie, inferior temporal gyrus and ventral temporal cortex) that tend to show dense concentrations of neuritic plaques.[14]

There are a number of potential ways that visual perceptual impairment may impact lexical-semantic processing in AD. Visual deficits may impact confrontation naming because of weakened visual input,[15] or a degraded internal image or perceptual representation[16,17] of the pictured item. Either of these impairments could potentially compromise one's ability to assimilate an incoming stimulus (eg, large animal-looking object) with a stored structural representation (eg, global and local visual form of an elephant). Recent research suggests that lower-level visual processing in AD may be predictive of the integrity of downstream cognitive processes that support naming and semantic processing.[15] Moreover, such sensory deficits may not only contribute to naming, but may also play a role in the integrity of stored structural representations or stored descriptions in long-term visual memory of an object's 3D structure. Chronic misperception (or misrepresentation) of visual stimuli could, in time, degrade stored structural representations, resulting in more insidious disturbances. According to Humphreys and Riddoch,[18] visual perceptual processes constantly update and recalibrate long-term visual memory, which may deteriorate in the presence of a perceptual deficit.

Consistent with many psycholinguistic models of naming and semantic access,[19,20] early sensory processes can potentially impact retrieval of the correct structural, semantic, and lexical representations. Over time, visual perceptual deficits could inaccurately update long-term visual memory as a result of weak visual input[21–23] and visual distinctive features. This hypothesis about the loss of visual distinctive features has often been invoked to explain the common pattern of category specific naming impairment seen in AD for naming natural kinds (eg, fruits, animals) relative to manufactured artifacts.[24–26] That is, computational investigations of the semantic structure of natural kinds show a high density of intercorrelated semantic features with high visual similarity (eg, many animals have tails, fur, 4 legs, ears, etc) relative to a higher degree of dissimarity among tools.[27] The subtle loss of visual distinctive features can impact the ability to distinguish among natural kinds and disproportionately impair naming among these category exemplars.[24,25,28,29]

There is compelling evidence to suggest that knowledge of distinctive semantic features is vulnerable in AD.[28,30] Alathari et al[30] found that AD participants identified fewer features of objects than controls and tended to list more features that are shared among category members instead of distinguishing features. They concluded that degradation of stored knowledge resulted in AD participants conceptualizing more shared features among concepts than healthy elderly participants. Again, when distinctive semantic features are related to an object's structure (ie, a horn distinguishing a rhinoceros from a hippopotamus) we propose that long-term visual perceptual impairment may degrade the internal representation of these structural features. Moreover, we suspect that this degraded knowledge of semantic features may differentially impair visual discrimination of pictured objects with high structural similarity that require additional structural feature knowledge when global form is not sufficient to decide whether they are the same or different. In other words, the visual system may use semantic knowledge as a top-down influence to interpret visual input when bottom-up information contains ambiguities.[31,32]

NAMING IN ALZHEIMER DISEASE

Several studies have investigated naming errors in AD by classifying errors as visual, semantic, or lexical in nature.[7,33] A common finding is that AD patients produce many semantic and/or thematic naming errors (ie, zebra for horse). The coarse criteria by which errors are divided can potentially overlook interactions among perceptual and lexical-semantic processes. For example, a disturbance in visually perceiving distinctive features may impact an individual's ability to access the appropriate semantic representation for an object (eg, chihuahua is named as cat), and possibly result in selection of a similar item from the same semantic category.[24] In turn, this type of coordinate naming error might reflect the bottom-up loss of a hierarchical semantic category structure when, in fact, visual perceptual deficits are a contributing factor. Errors are often only considered visual in nature if the incorrect name indicates a gross visual misrepresentation of the picture (ie, parking garage for harmonica).

As AD is a multifocal disorder, one must consider the possibility that visual perception and naming are 2 unrelated areas of concurrent decline. However, we find evidence of a possible link between the 2 processes in visual perception tasks that require discrimination of real objects. Joseph and Gathers[34] found that when healthy individuals underwent fMRI while carrying out a visual discrimination task between line drawings, they recruited relatively more anterior regions of the fusiform gyrus when the 2 drawings had high structural similarity, and relatively more posterior regions of the fusiform gyrus and inferior occipital cortex when the drawings were lower in structural similarity. Of interest, this posterior-anterior fMRI signal change that shifted with increased structural similarity of pictures occurred for naming as well.[35] These results are also consistent with functional imaging work reported by Tyler et al,[36] showing a posterior-anterior distinction in specificity needed to name items at either the level of superordinate domain (animal or tool) or at a more specific level (dog or cat) with increasing specificity of feature conjunctions as visual processing streams forward toward the perirhinal

cortex along the fusiform and inferior temporal gyri. (For converging evidence in animal models Bussey and Saksida[37]). Together, these findings suggest that fMRI signal in midanterior fusiform areas are related to processing of detailed object structure because these regions are sensitive to pictures with high structural similarity and pictures that require high specificity of structural processing, but not to other types of visual similarity (ie, color[38]). Damage to this common neural substrate devoted to processing of an objects' structure may impact performance on picture discrimination, matching, and naming tasks.

Visual discrimination tasks that vary in the degree to which they likely access structural and semantic knowledge may provide insight into potential visual perceptual or object recognition deficits in AD that may impact picture naming. Visual discrimination tasks that require matching of novel, complex shapes should not depend on access to a structural description system, as neither global form nor local visual processing should evoke a specific stored structural representation, semantic representation, or lexical entry. Similarly, processing of novel faces should not evoke structural, semantic or lexical information to help guide the process of discrimination. In contrast, visual discrimination tasks that require an individual to determine if 2 line drawings of real objects are of the same or different object in different views require accurate low-level visual perceptual processing and reference to a stored structural representation to help guide the decision.

AIMS OF THIS WORK

Our aim here is to determine whether visual discrimination abilities are predictive of naming and semantic association disturbances in AD. To better gauge the effect of visual perceptual disturbances on presemantic processing in AD, we examined correlations between specific measures of visual discrimination that vary in the degree to which they likely access structural and semantic knowledge and measures of naming and semantic association ability. Degraded semantic knowledge is well documented in this population from studies that used nonvisual tasks (such as naming to definition, feature listing, and priming),[30,39] and likely contributes to errors in picture naming. Thus, our goal was to determine the relative degree to which visual perceptual abilities may be related to picture naming deficits in AD.

We propose that, if sensory visual deficits are the primary visual contributor to picture naming impairment, then performance on all tests of visual discrimination, including those that do not involve access to a structural description system (ie, Benton Visual Form Discrimination Test, BVFDT and Benton Facial Recognition Test, BFRT), should show marked impairment that varies with naming abilities. If higher-level impairment in access to stored structural representations are the primary cause of picture naming difficulties, then visual perceptual tests that do not rely on these systems (BVFDT, BFRT) may be relatively spared (unless there is concurrent, but unrelated degradation to this system), but performance on tests that may require access to this information (Visual Discrimination Task[34]) should show impairment that correlates with naming impairment.

Our hypotheses are: (1) Performance on measures of visual discrimination will correlate with performance on measures of lexical-semantic abilities in AD participants. (2) Visual perceptual tasks that likely require access to a structural representation system will account for the most variance in predicting picture naming performance or semantic association performance in AD participants, indicating a common degraded process required to complete each of these tasks. (3) Individuals with AD will be more impaired than elderly controls on discriminating between pictures that have high structural similarity over low structural similarity on the Visual Discrimination Task because of a degraded internal structural description system.

MATERIALS AND METHODS

Participants

Participants (n = 40) included healthy community-dwelling elderly controls (n = 20) and individuals with probable AD (n = 20), recruited from extended care facilities, adult day programs, and an AD support group. Patients and controls were similar in their distributions of sex and age. The age range of the elderly control group and the AD group were 69 to 87 (mean = 82) and 67 to 96 (mean = 82), respectively. The AD group included individuals who fit the criteria for mild-moderate AD and had a score between the range of 11 to 26 on the Mini Mental State Exam.[40]

Inclusion criteria were natural or correctable visual acuity > 20/40; Mini Mental State Exam[40] scores of 25 to 30 for controls and 10 to 24 for cognitively impaired participants in the AD group (consistent with mild to moderate cognitive impairment); ability to show understanding of completing a visual discrimination practice test, whereby same-different judgments of line drawings must be made; no electroconvulsive therapy treatment within 2 years of recruitment or ≥ 10 lifetime electroconvulsive treatments at any time; no clinical signs of stroke or a Hachinski Ischemic Scale score ≥ 5; no history of neurologic dysfunction, as indicated by significant head trauma, migraine, seizures or developmental delay; and no history of visual or ocular problems, including, but not limited to, artificial lens implants, color blindness, or macular degeneration. Two AD participants scored above the upper limit for MMSE (26), but had a formal diagnosis of AD and were therefore, included in the study.

Potential participants were screened for eligibility using a screening checklist and by completing a form related to medical history. Caregivers or family members completed the medical history forms for AD participants. Testing took approximately 1.5 to 2 hours for elderly and

AD participants across 1 to 3 testing sessions depending on participant fatigue. Participants were either tested in their homes, adult day center, or a comfortable place for them, such as a labor union hall. All participants participated in these neuropsychologic tests to document abilities related to cognition, semantic knowledge, naming, and visual perception.

1. **The Mini Mental State Exam (MMSE)**[40] was used to screen for cognitive impairment. Participants were asked a series of questions related to orientation, attention, recall, repetition, comprehension, reading, and writing.
2. **The Pyramids & Palm Trees test (P&PT)**[41] assessed semantic knowledge by asking the participant to match pictures based on meaning [eg, (anchor) matches with (ship) but not with (canoe)].
3. **The Boston Naming Test (BNT)**[42] assessed confrontation naming by asking the participant to name drawings of objects (eg, mushroom).
4. **The Benton Visual Form Discrimination Test (BVFDT)**[43] required the individual to match patterns based on complex shapes and spatial construction.
5. **The Benton Facial Recognition Test (BFRT)**[43] required the participant to match pictures of faces based on facial features alone.
6. **The Visual Discrimination Task** is a task used in earlier research to investigate the functional organization of the human occipitotemporal cortex,[34] an area important for object recognition. The visual discrimination task involved the simultaneous presentation of 2 black-and-white line drawings of animals (eg, mammals, reptiles, birds) or fruits/vegetables that were of the same or different referents in different poses or views. (Figure 1). Structural similarity of the objects was determined based on judgments of healthy young adults in other experiments.[44,45] The pictures were black line drawings on white 5-inch squares presented side by side. The line drawings were approximately 4 inches in length or width, depending on the shape of the drawing. The white squares were presented on a gray rectangle, projected on a black computer screen.

The participants were told to indicate verbally whether the 2 pictures were of the same or different object by saying "same" or "different." The examiner then indicated the participants' response on the laptop computer. All responses were recorded by E-Prime 2.0 software (Psychology Software Tools, www.pstnet.com) to obtain response choices and accuracy. A query screen that read "Same or Different" in 48-point font appeared for 2 seconds before each picture pair. Each trial was 6 seconds in duration, including a 2-second "Same or Different" instruction and a 4-second presentation of the picture pair. Participants could respond at any time during the 4-second presentation. After controls participated in the study, it was determined that individuals with AD would not be able to complete the task in the 4-second time limit. As we were not investigating naming latency, we decided to allow additional time for visual discrimination in AD participants to provide better insight into behavioral performance. Therefore, AD participants were given unlimited time to discriminate between the picture pairs. This precaution was also included to prevent potential frustration associated with increased processing time for individuals with AD. Individuals with AD were also given the verbal prompt "Are these the same things or different things?" to elicit a response if they did not automatically respond to the visual query and picture pairs.

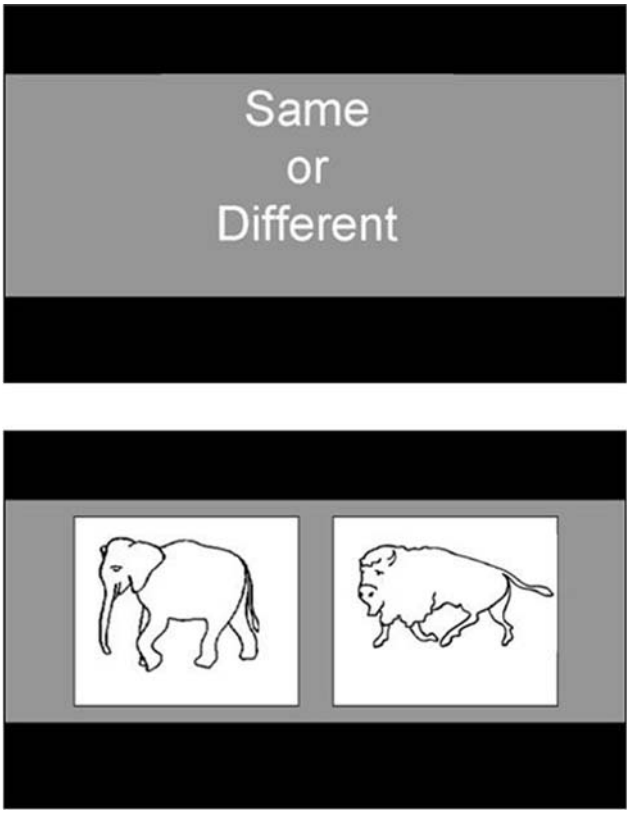

FIGURE 1. Query and picture presentation for the visual discrimination task.

The paradigm was presented in a block design, with each block consisting of either 2 high-similarity pairs of pictures (HIGH), or 2 low-similarity pairs of pictures (LOW). Figure 2 for examples of each. In addition, 1 pair of pictures in each block was of the same referent (SAME), but in different views or poses. Therefore, each block had 3 pairs of pictures, 1 of which was for the same referent in different poses, and 2 of which were of different objects that were either high-similarity or low-similarity. For example, 4 blocks of presentation may have consisted of these pairs of pictures: HIGH-SAME-HIGH, LOW-LOW-SAME, HIGH-HIGH-SAME, SAME-LOW-LOW.

The participants were instructed to identify if the pairs of pictures were of the same thing or different things. As the stimuli were presented simultaneously, no

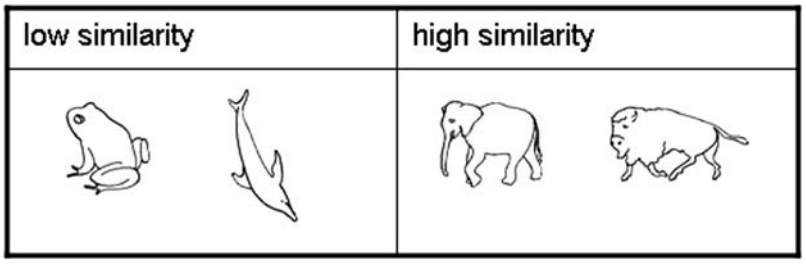

FIGURE 2. Sample low- and high-similarity picture pairs for the visual discrimination task. Low-similarity comparisons (eg, frog and dolphin) are less structurally similar than high similarity comparisons (eg, elephant and buffalo).

memory load was involved. In addition, no feedback was given to participants as to the correctness of responses, thereby reducing potential frustration associated with providing incorrect responses. The participants participated in 2 runs of 30 pairs of pictures each. There were a total of 60 pairs of pictures, 20 of the same referent, 20 low similarity, and 20 high similarity.

Each participant underwent training on the Visual Discrimination Task before beginning the task. During the training, the examiner presented 2 pictures simultaneously, and asked if the pictures were of the same or different object. The participant was reminded that 2 pictures of the same object may be in different poses or views. In this case, they are still of the same object, and the participant should say, ''same.'' Five pairs of objects were presented, and participants were given feedback as to the correctness of their response during training. For example, the examiner might say, ''Yes, that is correct, this picture is of a dog and this picture is of a dog. So, ''same'' is the correct response.'' Or, ''This picture is of a dog and this picture is of a pig.'' So, ''different'' is the correct response.''

RESULTS

AD patients performed out worse than elderly controls on all 5 measures as revealed by MANOVA: BNT [$F(1,38) = 18.40$, $P < 0.001$], P&PT [$F(1,38) = 14.35$, $P < 0.001$], BVFDT [$F(1,38) = 74.29$, $P < 0.001$], BFRT [$F(1,38) = 14.10$, $P < 0.001$] and Visual Discrimination Task [$F(1,38) = 30.88$, $P < 0.001$]. Table 1 for AD and elderly control mean scores on neuropsychologic measures.

Performance on Measures of Visual Discrimination Will Correlate with Performance on Measures of Lexical-Semantic Abilities in AD Participants

AD participants' scores were entered into a correlation analysis to determine whether there were significant correlations between performance on any of the visual perceptual measures with the BNT and/or the P&PT. Results indicated that performance on the Visual Discrimination Task that included pictures of animals, vegetables, and fruit was significantly correlated with performance on the tests of lexical semantic ability (BNT and PT&P; Figs. 3, 4). The Visual Discrimination Task also correlated with the other tests of visual perception (BVFDT and BFRT), but this correlation did not remain significant after applying Bonferroni correction for multiple comparisons. Table 2 for correlations.

The same correlation analyses for the elderly controls yielded no significant correlations among performance on any of the measures (Table 3).

Visual Perceptual Tasks that Likely Require Access to a Structural Representation System Will Account for the Most Variance in Predicting Picture Naming Performance or Semantic Association Performance in AD Participants

Scores on the BVFDT, BFRT, and Visual Discrimination Task from the participants with Alzheimer's

TABLE 1. Mean Scores on Neuropsychologic Tests by Group

Group (Max Score)	BNT (60)*	P&PT (52)*	VisDis (60)*	BVFDT (32)*	BFRT (54)*	MMSE (30)*
Normative scores	(n = 51)	(n = 13)		(n = 85)	(n = 286)	(n = 96)
		49-52		23-32	34-54	22-30
	44.7 mean	51 mean		29.73 mean	45.4 mean	27 mean
	9.6 SD				3.96 SD	0.9 SD
Elderly control (n = 20)	43-59	44-52	48-59	24-32	36-51	25-30
	53.45 mean	49.25 mean	56.5 mean	28.55 mean	45.85 mean	27.15 mean
	5.38 SD	2.59 SD	2.89 SD	2.48 SD	3.88 SD	1.79 SD
AD (n = 20)	9-58	24-51	39-57	13-32	29-51	14-26
	38.85 mean	43.10 mean	48.90 mean	20.40 mean	40.00 mean	18.80 mean
	14.24 SD	6.78 SD	5.39 SD	3.42 SD	5.79 SD	3.61 SD

Normative data for the tests: MMSE,[40] P&PT,[41] BVFDT, and BFRT,[43] BNT.[46]
*Indicates a significant difference between elderly control and AD groups.

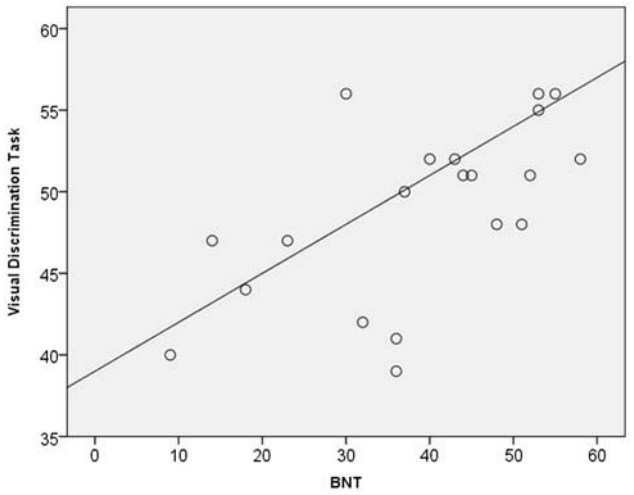

FIGURE 3. Correlation between AD participants' scores on the Visual Discrimination Task and the BNT.

disease were each entered into a stepwise regression to determine the extent to which they predicted performance on the BNT. The overall model was significant [$R = 0.61$, $R^2 = 0.37$, $F(1,19) = 10.59$, $P < 0.005$] in predicting performance on the BNT, however, performance on the Visual Discrimination Task ($\beta = 0.61$, $P = 0.004$) was the only independent predictor that accounted for significant variance ($R^2 = 0.37$), whereas the BVFDT ($\beta = -0.01$, $P = 0.95$) and the BFRT ($\beta = 0.03$, $P = 0.89$) did not significantly contribute to the model.

Scores on the BVFDT, BFRT, and Visual Discrimination Task by the participants with Alzheimer disease were entered into a stepwise regression to determine if they predicted performance on the P&PT. The overall model was significant [$R = 0.78$, $R^2 = 0.61$, $F(1,19) = 28.12$, $P < 0.001$] in predicting performance on the P&PT, however, performance on the Visual Discrimination Task ($\beta = 0.78$, $P < 0.001$) was the only independent predictor that accounted for significant variance ($R^2 = 0.61$), whereas the BVFDT ($\beta = -0.09$, $P = 0.96$) and the BFRT ($\beta = 0.11$, $P = 0.53$) did not significantly contribute to the model.

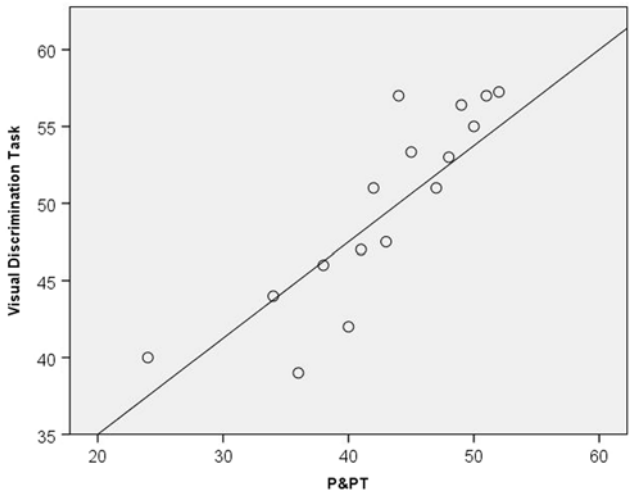

FIGURE 4. Correlation between AD participants' scores on the Visual Discrimination Task and the P&PT.

TABLE 2. Correlations For AD Participants

	BNT	P&PT	VisDis	BVFDT	BFRT
BNT	1	0.724*	0.609*	0.260	0.351
		0.000	0.004	0.268	0.130
P&PT	0.724*	1	0.781*	0.340	0.502†
	0.000		0.000	0.142	0.024
VisDis	0.609*	0.781*	1	0.444†	0.538†
	0.004	0.000		0.050	0.014
BVFDT	0.260	0.340	0.444†	1	0.526†
	0.268	0.142	0.050		0.017
BFRT	0.351	0.502†	0.538†	0.526†	1
	0.130	0.024	0.014	0.017	

Significance levels are below each R value in the chart. Only correlations significant at the 0.01 level remained significant when Bonferroni correction for multiple comparisons was applied.

*Pearson correlations significant at the 0.01 level (2 tailed).

†Pearson correlations significant at the 0.05 level (2 tailed).

Individuals With AD Will be More Impaired Than Elderly Controls on Discriminating Between Pictures That Have High Structural Similarity Over Low Structural Similarity on the Visual Discrimination Task

The differences between Visual Discrimination accuracy for high similarity, low similarity, and same pairs of pictures were assessed across the AD and controls in a mixed analysis of variance (ANOVA) to determine if the AD or healthy elderly participants' performance on the task varied depending on structural similarity. Group membership was the between participant factor, and similarity of pictures was the within participants factor. There was a significant main effect of structural similarity of pictures (low similarity, high similarity, and same) [Greenhouse-Geisser Corrected, $F(1.38,52.44) = 12.24$, $P < 0.001$] and group (AD or control) [$F(1,38) = 33.43$, $P < 0.001$], but the similarity by group interaction

TABLE 3. Correlations For Elderly Controls

	BNT	P&PT	VisDis	BVFDT	BFRT
BNT	1	0.354	0.391	−0.248	−0.014
		0.126	0.088	0.291	0.952
P&PT	0.354	1	0.333	0.149	0.061
	0.126		0.151	0.530	0.797
VisDis	0.391	0.333	1	0.114	0.180
	0.088	0.151		0.633	0.447
BVFDT	−0.248	0.149	0.144	1	0.118
	0.291	0.530	0.633		0.619
BFRT	−0.014	0.061	0.180	0.118	1
	0.952	0.797	0.447	0.619	

Significance levels are below each R value on the chart.
No significant correlations at the 0.05 level (2 tailed).

[$F(1.38,52.44) = 2.12$, $P = 0.15$] was not statistically significant.

Subsequent independent sample t-tests indicated that there were significant differences between groups for low-similarity pictures [$t(19.97) = 3.08$, $P < 0.05$], high-similarity pictures [$t(32.41) = 2.64$, $P < 0.05$], and same pictures [$t(24.57) = 4.78$, $P < 0.001$].

DISCUSSION

Our results indicate significant relationships between visual discrimination abilities of pictured objects with performance on tests of picture naming and visual semantic association. Thus, we find that the ability to visually discriminate line drawings of nameable objects may play a role in performance on picture tests typically used to assess lexical semantic abilities in persons with AD. These findings are consistent with studies showing that incorrect responses on confrontation naming tasks are likely to be visually similar to the target,[47] and as less perceptual information is available, AD participants tend to make more naming errors than controls.[48] Moreover, the opportunity to use nonverbal sensory information, such as touch, increases AD participants' abilities to name objects.[49]

In this study, performance on all tests of visual discrimination and lexical-semantic abilities was significantly worse in AD participants than in elderly control participants, indicating that the AD participants were impaired in visual perceptual, semantic, and naming abilities. AD participants' performance on 1 visual perceptual task, the Visual Discrimination Task, correlated with both the P&PT and the BNT, indicating a relationship with naming and semantic association abilities. Of the 3 visual perceptual tasks, performance on the Visual Discrimination Task was the only significant predictor of performance on the BNT and the P&PT.

Three visual discrimination tasks that vary in the degree to which they likely access structural and semantic knowledge were used to provide insight into the level at which impairments in the visual perceptual system impact picture naming. Of the 3 tasks, we suspect that the BVFDT that requires matching of novel, complex shapes that are not easily named should not depend on access to a structural description system, as global and local processing should not evoke a specific stored structural, semantic, or lexical entry. Similarly, processing of novel faces in the BFRT should not evoke structural, semantic, or lexical information to help guide the process of discrimination, as it is unlikely that matching an earlier mental image to the percept would assist with the task. In contrast, discrimination of animals, fruits, and vegetables on the Visual Discrimination Task likely would have been supported by access to information about the known structure of objects to complete the task, as objects were matched across different views or poses.

We proposed that if low level visual deficits were the main contributor to naming impairment, then the BFRT and BVFDT, which do not likely involve access to a structural description system, should have shown marked impairment that varied with naming abilities. Individuals with AD were significantly impaired on the BFRT and the BVFDT, but this impairment did not correlate with naming impairment, implying that, although low-level visual deficits may have existed, they were not the main source of picture naming difficulties.

We also proposed that, if higher-level impairment in access to stored structural representations were the primary contributor to picture naming difficulties, then visual perceptual tests that do not rely on these systems (BVFDT, BFRT) may be relatively spared, but performance on tests that may require access to this information to complete the task (Visual Discrimination Task) should show impairment that correlates with naming impairment. Results indicated that the BVFDT, BFRT, and Visual Discrimination Task were all impaired in AD participants, but only performance on the Visual Discrimination Task showed a relationship with naming abilities. One possible explanation for this finding is that both low-level visual deficits and higher-level structural representations of objects were impaired in the AD participants, but only the deficits in higher level structural representations produced a large enough effect to impact naming.

This explanation is supported by the finding that AD participants carried out significantly worse than elderly controls on each of the 3 types of pictures presented in the Visual Discrimination Task. One might argue that the significant difference in performance between groups indicates the contribution of deficits in low-level perceptual processing to difficulty in discriminating low-similarity pictures, and problems with presemantic structural descriptions required for discriminating high-similarity pictures. It has been hypothesized that low-spatial frequency information, such as global form, may be sufficient to distinguish between line drawings with low-similarity ratings, whereas line drawing that are high in similarity may need fine-detailed visual discrimination, which is processed in more anterior aspects of the ventral visual stream.[50] Moreover, discrimination of high-similarity line drawings may require access to stored structural representations to make a decision. Both low-similarity and high-similarity pictures were more difficult for AD participants than for healthy controls, possibly indicating concurrent deficits in low-level visual processing and higher-level structural representations.

An alternate explanation for the relationship between performance on visual discrimination and naming is that there are 2 separate cognitive processes that declined simultaneously. This alternative is plausible, given the diffuse neuropathology in AD and the wide range of cognitive decline in our participants, as evidenced by MMSE scores, but we believe there may be a causal link for these reasons. Other tests of visual perceptual abilities (BFRT and BVFDT) did not produce significant correlations with naming. The major distinction was that the Visual Discrimination Task utilized nameable objects, whereas the other visual perceptual tasks did not. The BNT and P&PT also use nameable

items, which may elicit a mental image or stored structural representation prior to semantic access. We propose that the integrity of this structural representation system may be the causal link between visual processing deficits and language deficits in the AD participants. Moreover, the finding of a common neural substrate between discrimination and naming of line drawings[34] indicates that damage could impact both processes. Specifically, fMRI signal found in midanterior fusiform areas show a posterior-anterior shift corresponding to low versus high-structural similarity, respectively.

As the Visual Discrimination Task used real, nameable objects, it may have been a strong predictor of naming and semantic association abilities by tapping into a visual process that occurs at a stage before naming, such as comparing visual percepts to stored structural representations. Degradation of structural knowledge could account for the deficits in the Visual Discrimination Task, BNT, and P&PT, but another deficit, such as low-level visual processing, would have to have been present to produce the disturbances in the BFRT and the BFVDT.

In line with the structural degradation theory, Done and Hajilou[16] found that AD participants needed a more visually complete object representation before they could correctly identify pictures of familiar objects, but performance on visually degraded words was similar for AD participants and controls. They concluded that, in early stages of AD, there is some degradation of structural knowledge thought to be presemantic representations of objects within the visual perceptual system in addition to degradation of semantic representations. Furthermore, analysis of AD naming errors for visually intact pictures showed predominantly semantic level deficits that were characterized by substantial categoric or circumlocutory errors, but few pure visual confusion errors. Therefore, the degradation of structural knowledge may not result in obvious visual perceptual errors, but instead impact the ability to access appropriate semantic representations and, therefore, cause semantic errors in naming.

CONCLUSIONS

Our results indicate that, as Done and Hajilou[16] suggest, perceptual and semantic processing that occurs with naming may be informed by outputs of the other stages. Low-level visual perceptual errors, such as the inability to perceive visual features, or higher-level errors in mapping perceived features onto a stored structural representation, could impact selection of the correct semantic description downstream. This visual perceptual deficit could be manifest as difficulties in picture naming or semantic association impairment. The findings of this study are consistent with the position of Rogers et al,[51] who postulated that performance on individual semantic tests may reflect the abnormal functioning of other cognitive faculties that provide input to the semantic system. Our findings suggest that there is a common deficit in discrimination of pictures using nameable objects, picture naming, and semantic association of pictures in AD. Future studies may investigate whether a treatment approach targeting visual discrimination abilities improves lexical-semantic performance in this population.

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