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Establishing visual category boundaries between objects: A PET study

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Abstract

Individuals with Alzheimer's disease (AD) often have problems in recognizing common objects. This visual agnosia may stem from difficulties in establishing appropriate visual boundaries between visually similar objects. In support of this hypothesis, Saumier, Arguin, Chertkow, and Renfrew (2001) showed that AD subjects have difficulties in establishing visual category boundaries between continuously graded shapes. In an attempt to investigate the neural basis of these impairments, the current study required a group of neurologically healthy elderly participants to categorically classify a series of ellipses varying in width while regional blood flow changes were measured using positron emission tomography (PET). Two categorization conditions were compared in order to isolate changes in cortical activity that dissociated the categorization of shapes situated either near or far from a category boundary that divided the width continuum. The participants produced a discontinuity in the probability and speed of categorizing the shapes at some point along the continuum, suggesting that the objects were classified into distinct categories. Moreover, a comparison of the PET scans obtained while the subjects were categorizing the shapes situated near vs. far form the category boundary revealed significant differences in cortical activity in the parietal and frontal brain areas. These findings suggest that both visuo-spatial and decision making mechanisms may be involved in establishing categorical distinctions between continuously graded stimuli. It is proposed that the functional role of the parietal and frontal cortical regions in establishing visual boundaries between categories of objects may be relevant for understanding object recognition impairments in AD.

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1. Introduction

Earlier research has shown that Alzheimer's disease (AD) patients manifest object recognition impairments, which tend to be related to problems in categorizing visually similar objects (e.g., see Watmough & Chertkow, 2002, for review). These impairments may arise because the perceptual boundaries between object categories rep-

* Corresponding author. *E-mail address:* dsaumi@po-box.mcgill.ca (D. Saumier). resented in their disrupted memory system are uncertain or fuzzy. Saumier, Arguin, Chertkow, and Renfrew (2001) tested this hypothesis by requiring a group of mild to moderate AD patients to categorize a series of eight computer-generated ellipses that varied along a continuum of width on the basis of two shape prototypes corresponding to the extremes of the shape continuum. All participants showed a discontinuity in the probability of categorizing the shapes, suggesting that the objects were classified into distinct categories. However, the magnitude of this categorical effect was significantly less pro-

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nounced in the AD patients than in the control group. These categorical perception problems are quite general and apply to stimuli that are devoid of semantic content. This provided evidence that semantic memory deficits in AD patients may arise from difficulties in establishing pre-semantic perceptual boundaries that would otherwise serve to support decisions as to whether an object is a member of a category or not.

Although visual categorization impairments in AD have been firmly established, the neural basis of these deficits remains to be elucidated. The current study addressed this issue by having a group of neurologically healthy elderly participants perform a visual categorization task involving ellipses while regional blood flow changes were measured using positron emission tomography (PET). Two categorization conditions were completed by the same subjects in order to isolate changes in cortical activity that dissociate the categorization of shapes situated either near or far from a category boundary that divided a stimulus continuum. It was hypothesized that categorizing shapes situated near the category boundary would impose greater processing resources on those cortical regions that are involved in establishing visual boundaries between categories of objects.

2. Methods

2.1. Participants

Eight English speaking non-demented (as assessed by standardized neuropsychological testing) healthy and independently living elderly subjects (4 men and 4 women) participated in the experiment. Mean age was 72.6 y.o. (SD = 6.1).

2.2. Stimuli

The stimuli were 10 black filled 2D computer-generated ellipses that varied in terms of width. The shapes were generated by constructing two ellipses corresponding to the end points of the width continuum, and by interpolating eight intermediate ellipses with a constant width difference between successive shapes. All ellipses were 5 cm in height. The respective widths of the thinnest and widest ellipses were 3.5 and 4.2 cm, and each neighboring pair of ellipses along the continuum differed by 0.3 cm.

2.3. Procedures

Perceptual categorization was tested on the basis of whether subjects classified ellipses that were distal (shapes 1, 2, 7, or 8) or proximal (shapes 3, 4, 5, or 6) to the midpoint of the shape continuum. The proximal or distal shapes were tested in two separate blocks of 32 trials. On each trial, a 500 ms fixation point (Geneva 24 point font) appeared in the center of the monitor, followed 500 ms later by three simultaneously presented shapes. An intermediate ellipse was presented in the center of the monitor, with each of the endpoint ellipses displayed 7 cm to the left and right of the intermediate ellipse. The stimuli remained in view for a duration of 3500 s. An inter-trial interval of 1 s elapsed before the next trial began. Within each block, the eight intermediate ellipses were shown in a random order and in equal numbers within each block. The endpoint ellipses were presented an equal number of times on the left- and right-hand side of the monitor for each intermediate ellipse.

The Proximal and Distal categorization conditions were randomly ordered across subjects. For each condition, subjects were asked to respond as quickly as possible and no feedback was provided regarding the accuracy of their responses.

3. PET

PET scans were obtained from an ECAT EXAT HR + (CTI/SIEMENS) tomograph in a 3D acquisition mode. Transverse and axial resolution of scanning was 4.5-5.8 and 4.9-8.8 mm, respectively. Using the bolus H₂¹⁵O (10 mCi) methodology (Raichle, Martin, Herscovitch, Mintum, & Markman, 1983), a 60 s scan measuring normalized cerebral blood flow (CBF) was obtained from the beginning of each categorization task. The sum of the PET images across all frames were calculated for each scan. Automatic PET-to-PET registration was used in order to correct for between-scan head movement prior to matching the MRI and PET data sets. This method uses the first summed PET scan for a particular subject as the registration target for each subsequent summed PET scan. Each subject's summed PET image, which encompassed the entire cerebrum and 3/4 of the cerebellum, was realigned and transformed into standard Tailarach space, and then co-registered with a pre-experimentally acquired MRI scan of that individual. The subtraction analysis involved calculating a t value at each voxel by dividing the mean CBF difference by its standard deviation pooled across all brain voxels. Significant increases in CBF were detected on the basis of a 3D Gaussian random field theory (Worsely, Evans, Marrett, & Neelin, 1992), which corrects for multiple comparisons across brain volume.

During scanning, the subject's head was immobilized with a customized head holder device (vac-Lock,k MED-TECH). The visual stimuli were presented on a monitor positioned above the subjects at a viewing distance of approximately 75 cm. One scan was performed for each subject in each condition (i.e., proximal and distal). Download English Version:

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