The Right Hemisphere as an Anomaly Detector: Evidence from Visual Perception

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V. S. Ramachandran (1998) has suggested that the right hemisphere, which tends to be specialized for the analysis of global-level information, serves as an anomaly detector. Its role is to judge whether a given percept is possible and whether there are elements of that percept that seem incongruent with the other elements. In contrast, the left hemisphere tends to create a "story" to make sense of the incongruities. In the current study, pictures of possible or impossible objects were displayed for brief exposure durations to either the left visual field/right hemisphere or to the right visual field/left hemisphere. The results provide tentative support for the work of Ramachandran. In male participants, the right hemisphere was superior to the left in detecting impossible objects. © 2002 Elsevier Science (USA)

INTRODUCTION

It is well known that the two hemispheres of the brain serve different functions in the interpretation of visual information (Springer & Deutsch, 1998). However, some of the specific specializations are still not agreed upon, particularly those related to the analysis of complex visual images. Ramachandran (Ramachandran & Blakeslee, 1998) has suggested that the right hemisphere, which tends to be specialized for the analysis of global-level information, contains an anomaly detector. This anomaly detector analyses information (e.g., verbal material, information pertaining to body image, perceptual items) for the presence of features that render this information logically impossible, or incompatible with memorial representations pertaining to this information.

Ramachandran uses two lines of evidence for the anomaly detector being located in the right hemisphere. First, his own work with anosognosic patients (Ramachandran, 1995) implies that the right hemisphere is critical in detecting anomalies. Left hemiplegic patients who have damage to the right parietal lobe often do not consciously admit to having any sort of paralysis; rather, they adamantly claim to be fully mobile—often confabulating a story to account for the incongruity between their claims of being healthy and their inability to move the left side of their body (e.g., "I'm just really tired"). Of note is the fact that this anosognosia only occurs for right parietal-damaged patients. Patients with left hemisphere damage are fully aware of being paralyzed on the right side of their body. Thus, the right hemisphere can detect anomalies in body image whereas the left hemisphere cannot. Second, research by Gardner (1993) has shown that patients with right hemisphere damage have difficulty recognizing the incongruities in "garden path sentences." In these sentences, there is an unexpected twist at the end of the sentence that contradicts the beginning. The resulting sentence makes grammatical sense but is logically anomalous. Ramachandran (in Ramachandran & Blakeslee, 1998) suggests that the inability of right hemisphere patients to notice the resulting absurdity is another failure of the anomaly detector.

In applying the notion of the anomaly detector to visual perception, Ramachandrin's theory finds some support in neuroimaging and hemispheric specialization studies. Using positron emission tomography (PET) scans, Frith and Dolan (1997) have demonstrated, using neurological patients, that a small area of the right parietal
lobe becomes activated when there are discrepancies between a patient’s movement and the visual image of that movement. This finding is consistent with the literature on the hemispheric specialization of visual perception. When perceiving visual information, the right hemisphere tends to be more efficient at processing global features containing low spatial frequency information (see Hellige, 1995, for a review). In other words, the right hemisphere is superior to the left at processing “the big picture.” In contrast, the left hemisphere is more efficient at processing local information containing high spatial frequency information. The focused nature of left hemisphere perception may interfere with its ability to detect how individual features make an entire object anomalous.

The current study is an extension of the idea that the right hemisphere is superior to the left in detecting anomalies. In this study, two types of objects were used, line drawings of familiar objects (Snodgrass & Vanderwart, 1980) and line drawings of novel shapes (Williams & Tarr, 1997) that were based on sets of irregular polygons. Line drawings were briefly displayed to either the left visual field (which projects to the right hemisphere) or the right visual field (which projects to the left hemisphere). For both familiar and novel objects, half of the objects were rendered impossible. The familiar items were altered on the computer such that they became anomalous items (e.g., a car with square wheels). For the unfamiliar objects, logically possible polygons were altered so that they became structurally impossible. We predict that, consistent with the work of Ramachandran, the right hemisphere will be superior to the left in impossible objects.

METHOD

Participants

Twenty-four students (14 females and 12 males) participated in this study in exchange for course credit in an introductory psychology class. All participants were right-handed (as confirmed by the Waterloo Handedness Questionnaire) and had normal or corrected-to-normal vision.

Stimuli and Apparatus

Two sets of objects, one familiar and one unfamiliar, were used. The familiar items were taken from the Snodgrass and Vanderwart (1980) set of line drawings. Items were altered into “impossible objects” using Adobe Photo Editor such that changes rendered the objects functionally unusable and thus anomalous (e.g., a car with square wheels). Figure 1 contains an example of a possible and an impossible object from both the familiar and unfamiliar object sets.

The unfamiliar items were taken from a set of irregular polygons used by Williams and Tarr (1997). One set of forty line drawings was constructed such that the resulting polygon could exist in real space (i.e., it was a possible object). The other set of forty line drawings was based on the possible objects; however, each of these objects contained three alterations of structural features. The resulting irregular polygon could not exist in real space (i.e., it was an impossible object).

These stimuli were presented on a 12” color monitor connected to a Macintosh 650 Centris computer. The experiment was run using PsyScope software. The polygons were presented to the left or to the right of the center of a screen. The side of presentation and the type of object being presented was randomized with the constraint that all participants were to receive an equal number of possible and impossible figures in both the left and right visual fields. The presentation of each stimulus was
FIG. 1. Displayed in (A) are two sample stimuli based on Snodgrass and Vanderwart (1980). The right object is a picture of a normal watering can, whereas the left object has been structurally altered to such that its functional usefulness has been reduced. These are familiar objects. In (B) are two samples of stimuli based on Williams and Tarr (1997). The left item represents the possible version while the right represents the impossible version. These are unfamiliar objects.

in a 9 × 9 cm area the center of which was 4.5 cm from fixation. The line drawings were black and were presented on a white background. These stimuli were viewed from a distance of 35 cm. Participants indicated whether the presented stimuli were possible or impossible stimuli by pressing one of two buttons on a Button Box connected to the computer with their index fingers. The hand of response was counterbalanced so that the left and right index finger were each used to respond to both types of items (possible and impossible) and both stimulus sets (familiar and unfamiliar). Participants were instructed to keep their fingers on the response keys for the duration of the trial and to respond as quickly and as accurately as possible.

Procedure

Before beginning the computer task, participants were asked to complete the Waterloo Handedness Questionnaire and the Waterloo Footedness Questionnaire (Elias, Bryden, & Bulman-Fleming, 1998). Participants were also asked to confirm that they were able to clearly see the computer screen. Upon completion of the questionnaires, participants were given instructions for the computer task.

Each of the four blocks of trials on the computer task was preceded by a set of eight practice trials characteristic of the test trials described below. Each test trial began with a fixation cross that was displayed for 500 ms. After the fixation cross disappeared, a possible or an impossible object was presented to the left or right of fixation. The object remained on the computer screen for 150 ms (the approximately
duration of an eye saccade). Participants responded as quickly and as accurately as possible to the stimulus. No feedback was given on the test trials. After each trial, there was a 1000 ms delay before the next trial began automatically.

RESULTS

Mean accuracy and response times were calculated for each subject within each factor. Response times were analyzed for outliers using a trimming method that removed outliers more than three standard deviations away from the individual participant's response-time means. Error rates were high for some participants and were approximately 30% across the anomalous conditions and 25% across the normal conditions. However, no error rates approached chance and all data collected was used in the analysis.

A repeated-measures analysis of variance was conducted on response time and accuracy. The effect of gender was treated as a between-subjects variable. There were no main effects or interactions with reaction time for males or females (all F's < 1). In regard to the accuracy data, there was a significant main effect object type (impossible vs possible) for both the familiar and the unfamiliar items, \( F(1, 26) = 74.64, p < .001 \) and \( F(1, 26) = 4.245, p < .05 \), respectively. Possible objects

\[\text{FIG. 2.} \quad \text{A graphical representation of means found for male subjects. Graph (A) displays corresponding data from male subjects when tested using possible and impossible familiar stimuli presented in the left and right visual field. Graph (B) shows male subjects' accuracy scores in test trials presenting possible and impossible polygon line drawings in the left and right visual field.}\]
were generally responded to more accurately than impossible objects, both for the
familiar (Snodgrass & Vanderwart, 1980) and unfamiliar (Williams & Tarr, 1997)
figures. A significant interaction of object type × visual field × gender was also
found for the unfamiliar objects, $F(1, 26) = 5.278, p < .03$. This result suggests that
the males were showing larger effects than the females.

Given the fact that females tended to show smaller effects than males, we hypothe-
sized that the anomaly detector may be more lateralized in males than in females.
Therefore, we analyzed the data from males separately. The means for these data are
presented in Fig. 2. The resulting analysis was a 2 (object type) × 2 (visual field)
× 2 (familiarity) repeated-measures ANOVA. There was a main effect of familiar-
ity, with the familiar items resulting in more errors than the unfamiliar items, $F(1,
11) = 5.29, p < .05$. As well, the main effect of object type (possible vs. impossible
was significant, $F(1, 11) = 22.00, p < .001$. Critically, a marginally significant object
type × visual field interaction was found for males, $F(1, 11) = 2.945, p = .057$.
Male participants detected anomalous stimuli presented in the left visual field more
accurately than in the right visual field.

DISCUSSION

The results of this experiment provide tentative support for the notion of a right-
hemisphere anomaly detector. In male participants, there was a tendency for the right
hemisphere to be superior to the left detecting impossible objects.

It is possible that the tendency for males to be better than females at detecting
impossible objects is due to a general superiority in visuospatial skills. However,
males performed at slightly higher levels than females when dealing with familiar
objects (i.e., objects for which participants have semantic and memorial representa-
tions). Thus, the effect cannot be entirely accounted for by a gender difference in
basic visuospatial abilities.

One of the more salient aspects of the data was that the anomaly detector appears
to be more lateralized to the right hemisphere in males than in females. For both the
familiar and the unfamiliar objects, males showed a larger right hemisphere advan-
tage than did females. This gender difference could be due to the fact that, in general,
males show stronger lateralization of function than do females (Springer & Deutsch,
1998). Given this fact, it is not surprising that the predicted right-hemisphere advan-
tage was marginally significant in males but was not significant in females.

Previous work (Dolan & Frith, 1997; Ramachandran, 1995) has demonstrated that
the right hemisphere appears to be able to detect incongruities between the visual
perception of a movement and the biofeedback related to that movement. However,
all of this previous research has involved multiple sensory modalities (Ramachan-
dran, 1995) or semantics (Gardner, 1993). The current experiment extends the scope
of the anomaly detector from higher level cognitions to lower level visual perception.
Whether this lower level anomaly detector influences performance on other perceptual tasks has not yet been studied. This, along with the possibility of multiple
anomaly detectors for different levels of analysis, is an issue to be settled empiri-
ically.

ACKNOWLEDGMENTS

This research was supported by a grant from the Natural Science and Engineering Research Council
(NSERC) of Canada to M.J.D., by an NSERC post-graduate scholarship to S.D.S., and by an NSERC
undergraduate student award to W.J.T. This paper benefited from comments from Genevieve Desmarais.
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This is doi:10.1006/brcg.2001.1420.

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Movement in the Ipsilesional Hand Is Segmented Following Unilateral Brain Damage

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Unilateral stroke results in hemiplegia or hemiparesis of the contralateral side of the body. The ipsilateral side of the body, the so-called "good" side, is often assumed to have no deficit. However, there is increasing evidence that the function of the unaffected limbs, especially the upper extremities, is different from that of normal age-matched controls. In the present study, we examined the motor control of both hands of chronic stroke subjects, 6 with left hemisphere brain damage (LHBD) and 5 with right hemisphere brain damage (RHBBD). The control group consisted of 5 normal age-matched subjects. The task of the subject was to move a handle by flexing his/her fingers until the target position was reached. The target position was set as 33% of the range of each subject. No time constraints were imposed. The movements of the normal subjects were basically smooth, with few hesitations. In contrast to this, the movements of both hands in the two stroke groups were segmented and characterized by multiple starts and stops. As compared to normals, the time to reach the target, the number of pauses during the movement, and the percent of time spent in pauses, were significantly greater for both hands of the LHBD group. In the RHBBD group, the percent of time spent in pauses was significantly greater than the control group for the ipsilesional hand. The increased segmentation seen in the movements of the ipsilesional, as well as the contralesional, hands of the hemiplegic subjects suggests that the motor deficits in stroke patients may be due to a global inability to correctly plan and carry out movements. © 2002 Elsevier Science (USA)

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INTRODUCTION

Following a unilateral cerebrovascular accident, the clearest evidence of sensory-motor deficits is typically seen in the limbs contralateral to the side of the lesion.