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Right hemisphere involvement in the attentional blink: Evidence from a split-brain patient

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Abstract

When two masked targets are presented in a rapid sequence, correct identification of the first hinders identification of the second. This attentional blink (AB) is thought to be the result of capacity limitations in visual information processing. Neuropsychological and neuroimaging evidence implicated the right hemisphere as the source of this processing limitation. We investigated this idea by testing a split-brain patient (JW) in a modified AB task. The targets were presented in the same visual field (VF), and thereby to the same hemisphere, or in different VFs. We observed evidence of an AB both when the targets were presented to the same hemisphere and when the targets were presented to different hemispheres. However, the AB was more severe when the second target was presented to the RH. Our results are consistent with the notion that the right hemisphere plays a critical, but not unique, role in limited-capacity visual processing.

1. Introduction

Selectivity in sensory processing, by definition, implies a gain and a loss. The gain is what was selected. The loss is what was not selected. So it is with human visual selective attention. For example, when two masked targets are presented in a rapid sequence, selecting the first target comes at the price of missing the second target for about 500 ms. This cost—called an attentional blink (AB)—is thought to reflect capacity limitations in visual information processing, the time-course of which represents the selection-time of visual attention (for a review see Shapiro, Arnell, & Raymond, 1997). A critical question in the study of the AB, and the nature of the underlying capacity limitations more generally, is what neural mechanisms subserve these capacity-limited attentional systems?

Evidence from neuropsychological and neuroimaging studies suggest that the capacity limitations observed during the AB are mediated largely by a right-lateralized brain system including both frontal and parietal cortex (Husain, Shapiro, Martin, & Kennard, 1997; Marois, Chun, & Gore, 2000). A strong interpretation of these data predicts that if the right hemisphere (RH) is the locus of capacity limitations during the AB, then the AB should be observed only when both targets are presented to the RH. We assessed the viability of this interpretation by testing a split-brain patient (JW) in a modified AB task. In this task, two target letters were presented sequentially, each were masked, and separated by a brief temporal interval. The targets were presented in the same visual field (VF), and thereby to the same hemisphere, or in different VFs.

2. Method

2.1. Participants

The split-brain patient, JW, is a 47-year-old right-handed male who underwent a callosotomy as treatment for intractable epilepsy. The patient's complete case

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history and performance on a variety of cognitive tasks has been reviewed elsewhere (Gazzaniga, 1995). Six college-age controls also participated in the experiment. All of the participants were right handed and all reported having normal or corrected-to-normal vision.

2.2. Stimuli

Alphanumeric stimuli subtended approximately .8° of visual angle. The letter-targets were selected randomly without replacement from a set of eight uppercase letters of the English alphabet, including B, L, P, F, S, D, U, and R. Mask stimuli were digits (2–9) and were selected randomly with replacement from the set of digits. The stimulus durations for the patient was 114 ms, but was reduced to 86 ms for the control subjects because pilot testing revealed that performance was too high using the same stimulus duration experienced by JW. The visual display consisted of a fixation point and four possible target locations, two in each visual field, marked by placeholders. The center of each target location was offset approximately 2° from the horizontal and vertical meridians.

2.3. Design

There were three independent variables: (1) the visual field (VF), right or left, in which the first target was presented; (2) the VF, right or left, in which the second target was presented; and (3) the temporal interval, or lag, between the targets, which was either 114, 298, or 696 ms. These intervals will be referred to as lags 1, 2, and 3, respectively. These conditions were combined factorially and randomly intermixed within a session. Each session consisted of 30 trials in each of the conditions, resulting in 360 total trials that were divided into 6 blocks of 60 trials.

2.4. Procedure

Each trial began with the presentation of a small fixation dot in the center of the screen. After a 500 ms delay, the first target was presented in any one of the four locations and then was backward masked by a digit. After the variable lag interval the second target was presented in one of the remaining three locations; half of the time it was presented in the same VF as the first target and half of the time in the opposite VF. After a 500 ms interval, a response display appeared in each VF and it listed all the possible target letters. The patient pointed to the targets that were presented and an experimenter typed them into the keyboard. Control participants typed the target letters themselves. After the second letter was typed there was a 1000 ms delay and then the next trial began. A schematic representation of this paradigm is illustrated in Fig. 1A.

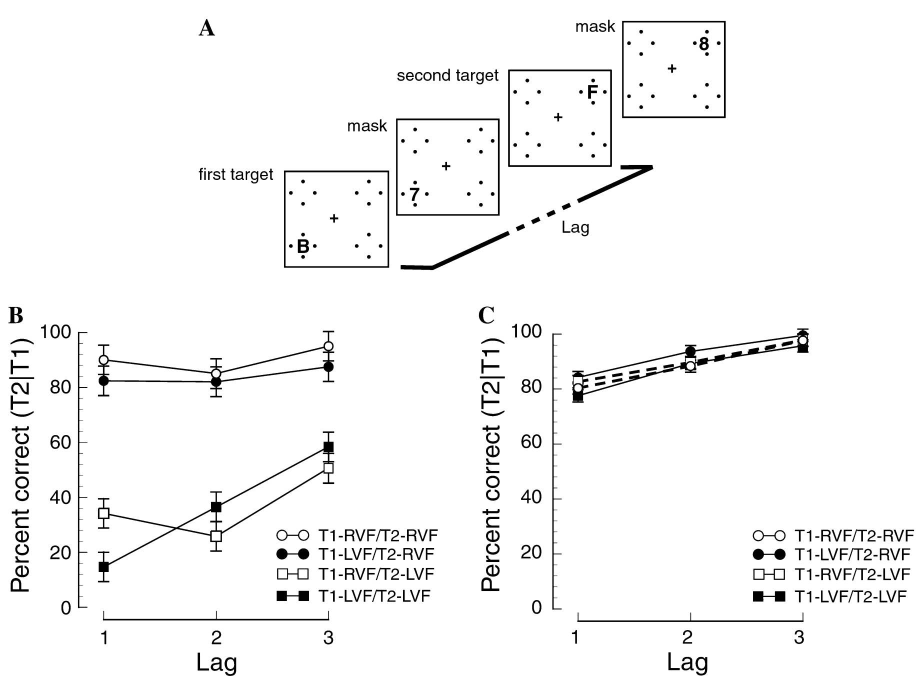

Fig. 1. (A) A schematic representation of the display sequences. (B) Results from JW. Shown are mean percentages of correct identifications of the second target, given accurate identification of the first target, as a function of the temporal lag between the first and second targets, first target location, and second target location. (C) Same as (B), except for the control subjects. Error bars represent standard errors of the mean. T1, first target; T2, second target; LVF, left visual field presentation; RVF, right visual field presentation.

3. Results

3.1. Patient data

JW participated in two sessions, run on separate days. Statistical analyses are based on the means of the experimental blocks (i.e., 12 blocks across the sessions). Mean percent correct identifications of the first target collapsed across lag were 76.1% when the first target was presented in the LVF and 93.9% when presented in the RVF ($t(11) = 5.83$, $p < .002$).

Estimates of second target identification accuracy are based on those trials in which the response to the first target was correct. Mean percentages of correct identifications of the second target as a function of VF and lag are shown in Fig. 1B. There were three statistically significant effects. First, there was an effect of lag ($F(2,22) = 22.10$, $p < .0001$, $MSE = 199.83$), such that overall performance at lag 1 (55.3%) and lag 2 (57.4%) was lower than at lag 3 (72.9%), indicative of an AB. Second, identification accuracy was lower when the second target was presented in the LVF (36.7%) vs. the RVF (87.0%) ($F(1,11) = 264.78$, $p < .0001$, $MSE = 344.26$). Finally, there was an interaction between lag and the VF in which the second target was presented, such that the effect of lag was larger when the second target was presented in the LVF vs. when it was presented in the RVF ($F(2,22) = 9.33$, $p < .02$, $MSE = 200.12$).

3.2. Control data

Mean percent correct identifications of the first target collapsed across lag were 95.4% when the first target was presented in the LVF and 95.2% when presented in the RVF ($t(5) = 0.12$, $p > .90$).

Mean percent correct identifications of the second target given correct identification of the first target as a function of VF and lag are shown in Fig. 1C. As with the results of the patient data, there was a significant effect of lag ($F(2,10) = 28.13$, $p < .0001$, $MSE = 58.27$), where identification accuracy was lowest at lag 1 (81.2%) and it improved monotonically as lag increased (lag 2 = 90.3%; lag 3 = 97.7%), demonstrating again the presence of an AB. Unlike the analysis of the patient data, however, the only other significant effect was the interaction between the first target VF and second target VF ($F(1,5) = 9.96$, $p < .03$, $MSE = 17.5$), whereby identification was accuracy was better when the targets were presented in different visual fields.

4. Discussion

Neuropsychological and neuroimaging studies implicate a role for the right hemisphere in capacity-limited processing during the AB (Husain et al., 1997; Marois et al., 2000). The present study tested a strong interpretation of these data—i.e., that the right hemisphere plays a unique role in the AB—by testing a split-brain patient on an AB task. In contrast to the strong interpretation, we found evidence of an AB when the targets were presented to the same hemisphere and when they were presented to different hemispheres. Importantly, however, the AB was most severe when the second target was presented to the right hemisphere (LVF), which is consistent with the previous neuropsychological and neuroimaging data. Overall, our results are consistent with the notion that the right hemisphere plays a critical, but not unique, role in limited-capacity visual processing.

We argue that the interaction between the location of the second target and the AB supports the notion that the right hemisphere subserves limited-capacity processing during the AB. But the fact that presenting the first target to either the LVF or the RVF produced an equivalent AB in the right hemisphere indicates one of two possibilities. One possibility is that attentional resources from the right hemisphere are appropriated whether or not the first target is presented to the right hemisphere. This would imply that the subcortical connections that are preserved in a split-brain patient might be sufficient for the left hemisphere to commandeer the capacity-limited processes of the right hemisphere. Alternatively, the right hemisphere resources might be occupied by shifting spatial attention to the RVF when the first target is presented there (for a detailed discussion of these alternatives see Mangun et al., 1994). In either case, it is clear that the relation between fields and hemispheric selection is asymmetric such that presenting the first target to the LVF (right hemisphere) does not seize limited-capacity processes of the left hemisphere.

In sum, the present study provides important behavioral support for the prevailing view that right hemisphere mechanisms subserve the AB. But our data also indicate that this view is incomplete. Processing demands that are engaged by presenting the first target to the RVF (left hemisphere) also appear to play a vital role. How LVF targets engage right hemisphere processes is an important, and intriguing puzzle that we are currently investigating.

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