Response Time of Stroke Patients to a Visual Stimulus

Francene Kaizer, BSc, Nicol Korner-Bitensky, MSc, Nancy Mayo, PhD, Rubin Becker, MDCM, FRCP, and Henry Coopersmith, BCL, MDCM, CCFP

We used a computer program to test response time among stroke patients in a clinical setting. Visual stimuli were presented to 82 hospitalized stroke patients, to 21 hospitalized controls, and to 76 nonhospitalized controls. Stroke patients had longer mean response times than controls. Patients with right hemispheric lesions had longer response times than those with left hemispheric lesions when the stimuli were presented on the left. The corresponding phenomenon of longer response times in patients with left hemispheric lesions to stimuli presented on the right was not observed. Patients with right hemispheric lesions with visual hemineglect had a longer mean response time than those without visual hemineglect when the stimuli were presented on the left or centrally, whereas the patients with right hemispheric lesions without neglect had a mean response time similar to that of patients with left hemispheric lesions. (Stroke 1988;19:335–339)

It has been well established that brain-injured individuals exhibit longer reaction times than noninjured subjects1-3; however, the effect of the side of the lesion is equivocal. Isagoda and colleagues found that stroke patients with right hemispheric lesions (RHL) took longer to respond than stroke patients with left hemispheric lesions (LHL) although, because of the small number of subjects (17 per group), Isagoda et al could not rule out chance as the explanation for this difference. These authors also noted that patients took longer to respond when a visual stimulus was presented on the side contralateral to the lesion. Howes and Boller, using an auditory stimulus, also reported longer response times in subjects with lesions of the nondominant hemisphere compared with patients with lesions in the dominant hemisphere. In contrast, others have not found differences in response times between patients with RHL and LHL.4-5

These inconsistent findings may be explained in part by differences in the types of patients studied. For example, only 26 of the 485 patients studied by Elsass and Hartelius had cerebrovascular disease, and only one of the stroke patients had a lesion in the parietal lobe, a site commonly affected by stroke and especially important in the accomplishment of visuospatial tasks.6-11 Even when patients with similar pathologies have been studied, the testing procedures differed and subject selection criteria varied.

In the past, response time has proven valuable as a research tool; more recently, the availability of easy-to-use computer programs has permitted the extension of response time tasks into clinical testing. The underlying purpose of our study was to determine whether, in a clinical setting, the study of response time could contribute further to our knowledge regarding the effects of stroke. The specific objectives of our study were to compare response times of hospitalized stroke patients with those of hospitalized and nonhospitalized controls, and to investigate the influence of the side of the lesion on response time.

Subjects and Methods

Subjects

A total of 179 subjects participated in this study: 82 stroke patients and 97 controls. The stroke group comprised those patients admitted to a 120-bed active rehabilitation hospital in Quebec, Canada, from May 1984 to March 1986. The participants were chosen from 293 consecutive admissions with a primary diagnosis of cerebrovascular accident. Forty-five patients with RHL and 37 with LHL participated. The side of the lesion was determined from the results of a computed tomogram (CT scan) and/or neurologic examination. Subjects were excluded if they had any of the following: bilateral motor or sensory loss, primary visual defects, previous stroke, other neurologic conditions, severe comprehension disorders, or confusion. Not all eligible patients could be assessed because of constraints in staff and time; however, we do not feel that any systematic selection process operated. Stroke patients were assessed for verbal comprehension by a speech pathologist and for visual hemineglect.12-15

The control group consisted of 21 hospitalized and 76 nonhospitalized subjects. The same exclusion criteria defined for stroke patients applied to the controls. Hospitalized controls were tested during a 2-week period in March 1986. The nonhospitalized controls, recruited from members of the hospital staff and visitors, were tested during the period from May 1984 to March 1986.
The characteristics of the participants are presented in Table 1. There were more men than women among the stroke patients; however, women predominated in the nonhospitalized controls subgroup. Whereas stroke patients and hospitalized controls were similar in age, the nonhospitalized controls were, on average, younger. All patients with RHL used their dominant (right) hand for the test; 26 patients with LHL (70%) used their nondominant (left) hand whereas 11 (30%) were able to use their dominant (right) hand.

**Procedure**

All subjects were tested on the "head free-to-move" version of the computer program REACT (Reaction Time Measure of Visual Field). This program is designed for a simple response time task: there is one type of stimulus and one type of response. The visual stimulus was presented on a 25 x 20 cm green phosphorous monitor. Subjects were seated in front of the monitor and instructed to tap the space bar of an Apple 2E keyboard as quickly as possible at the first sight of the stimulus. Subjects were told to keep their fingers positioned over the space bar between trials. The time between presentation of the visual stimulus and depression of the space bar was measured in milliseconds by the computer. In this program, intervals between presentations of the stimuli vary, preventing the subjects from developing a response pattern.

First, the visual stimulus appeared on the central axis of the screen. There were seven central trials; the first two were practice trials and were not counted. The next 18 stimuli appeared, at random, on either the left or right half of the screen. The first left trial and the first right trial were again not counted.

For each subject, three averages were calculated based on the five central trials, the eight left trials, and the eight right trials. A maximum response time of 12 seconds was assigned for any trial in which a subject failed to respond to the visual stimulus.

**Statistical Methods**

A comparison of the mean average response time between the stroke and control groups and between the LHL and RHL patients was carried out using linear regression. For the first comparison, response time was the regressor and the predictor was group (stroke patients or controls, denoted by a dummy variable). For the second comparison, side of the lesion (also denoted by a dummy variable) was used as the predictor. Age and sex were considered to be potentially confounding variables and, therefore, were included as covariates.

**Results**

**Comparison of Response Times**

In Table 2, the distributions of response times to visual stimuli appearing on the left are presented. Only one person in the control group had a response time >1.49 seconds, whereas 24 stroke patients exceeded this time. Similar distributions were observed for visual stimuli presented in the center and on the right.

In Table 3 the unadjusted mean response times for the stroke and control groups are presented. Stroke patients were compared to the control group on mean response time when the stimuli were presented on the left, in the center, and on the right of the screen. After accounting for the effects of age and sex, stroke patients had longer mean response times than controls for all fields of presentation (p = 0.0001). The mean response times for the four subgroups are also presented in Table 3. On average, RHL patients had the longest response times in all fields of presentation and the nonhospitalized controls had the shortest.

To explore the effect of the side of the lesion on response time, we compared RHL patients with LHL patients when stimuli were presented on the left, in the center, and on the right (Table 3). There were no differences in response time between RHL and LHL patients when the stimulus appeared in the center (p = 0.55). For stimuli presented peripherally, RHL patients had longer mean response times than LHL patients when the stimuli were presented on the left (p = 0.02), but the two subgroups of stroke patients did not differ when the stimuli were presented on the right (p = 0.31). These latter two comparisons (in the left and right fields of presentation) contrasted response times to visual stimuli presented contralateral to the lesion in one subgroup with response times to stimuli presented ipsilaterally in the other subgroup.

<table>
<thead>
<tr>
<th>TABLE 1. Characteristics of Subjects</th>
<th>Stroke patients</th>
<th>Controls</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>RHL (n = 45)</td>
<td>LHL (n = 37)</td>
</tr>
<tr>
<td>Mean age (years)</td>
<td>69.2 ± 10.6</td>
<td>65.1 ± 11.6</td>
</tr>
<tr>
<td>Men</td>
<td>29 (64%)</td>
<td>21 (57%)</td>
</tr>
<tr>
<td>Women</td>
<td>16 (36%)</td>
<td>16 (43%)</td>
</tr>
<tr>
<td>No. using dominant hand</td>
<td>45 (100%)</td>
<td>11 (30%)</td>
</tr>
</tbody>
</table>

RHL, right hemisphere lesion; LHL, left hemisphere lesion.

<table>
<thead>
<tr>
<th>TABLE 2. Distribution of Mean Response Times to Visual Stimuli Presented in Left Periphery</th>
</tr>
</thead>
<tbody>
<tr>
<td>Response time (sec)</td>
</tr>
<tr>
<td>------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>0-0.49</td>
</tr>
<tr>
<td>0.50-1.49</td>
</tr>
<tr>
<td>1.50-2.49</td>
</tr>
<tr>
<td>&gt;2.49</td>
</tr>
</tbody>
</table>

Data are percent. Some columns do not add to 100% due to rounding.
We also compared (again adjusting for the effects of age and sex) when each subgroup responded to stimuli in the field contralateral to the lesion and when each subgroup responded to stimuli in the field ipsilateral to the lesion (Table 4). The comparisons are presented in order of increasing disparity of means. As illustrated both here and in Table 3, RHL patients did not differ from LHL patients in the first comparison \((p = 0.31)\) but did differ in the last comparison \((p = 0.02)\). The additional comparisons presented in Table 4 showed that RHL patients had longer response times than LHL patients with presentations both contralateral \((p = 0.07)\) and ipsilateral \((p = 0.12)\) to the side of the lesions.

**Influence of Visual Neglect**

Unadjusted mean response times for stroke patients according to the presence or absence of unilateral neglect are presented in Table 5. When the effects of age and sex were taken into account, RHL patients with unilateral neglect reacted more slowly than those without unilateral neglect when the stimuli were presented on the left \((p = 0.02)\) or in the center \((p = 0.03)\). However, when the stimuli were presented on the right, there were no differences in response times between those with and those without neglect. For LHL patients there were no differences in response times (age and sex taken into account) between those with and those without visual hemineglect. The response times of RHL patients without neglect were closely similar to those of LHL patients taken as a whole \((p > 0.35)\) for all three fields of presentation.

**Influence of Verbal Comprehension**

We chose not to exclude patients with limited verbal comprehension but rather to provide nonverbal instructions when necessary. Fourteen (38\%) of 37 LHL patients had some difficulty with verbal comprehension, whereas none of the 45 RHL patients had difficulty. When the stimuli were presented in the center, the mean response time for patients with impaired verbal comprehension \((1.02 \pm 1.40)\) did not differ from that of those without impairment \((1.11 \pm 1.16)\); similar means and SDs were found for presentations on the left and right.

**Discussion**

Taking into account the effects of age and sex, hospitalized stroke patients had slower response times than controls (Table 3) in all three fields of presentation. These results, based on the measurement of response time in a clinical setting, are in accord with previous reports.

Among stroke patients, those with RHL had slower response times than those with LHL, but only when visual stimuli were presented in the left visual field (Table 3). If stroke patients are at a disadvantage when responding to stimuli in the field contralateral to the lesion, then we would have expected LHL patients to have longer response times than RHL patients to stimuli presented on the right. Yet, on average, LHL patients performed just as well as, if not better than, those with RHL. The two additional comparisons that were made (Table 4) enabled us to contrast response times to stimuli ipsilateral to the lesion on the one hand and contralateral to the lesion on the other hand. Under these two situations, RHL patients reacted more slowly than LHL patients \((1.75 \text{ vs. } 1.00 \text{ and } 2.10 \text{ vs. } 1.22, \text{ respectively})\); however, because of small sample size, there was a >5% probability \((0.12\) and

<table>
<thead>
<tr>
<th>Field of presentation</th>
<th>Stroke patients</th>
<th>Controls</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total ((N = 82))</td>
<td>Hospitalized ((n = 21))</td>
</tr>
<tr>
<td>Left</td>
<td>RHL ((n = 45))</td>
<td>LHL ((n = 37))</td>
</tr>
<tr>
<td>Mean</td>
<td>1.60*</td>
<td>1.00</td>
</tr>
<tr>
<td>SD</td>
<td>1.95</td>
<td>1.10</td>
</tr>
<tr>
<td>Central</td>
<td>Mean</td>
<td>1.26</td>
</tr>
<tr>
<td>SD</td>
<td>1.35</td>
<td>1.24</td>
</tr>
<tr>
<td>Right</td>
<td>Mean</td>
<td>1.10</td>
</tr>
<tr>
<td>SD</td>
<td>1.24</td>
<td>1.42</td>
</tr>
</tbody>
</table>

RHL, right hemisphere lesion; LHL, left hemisphere lesion; \(p\), probability after adjustment for age and sex. Data are seconds.

\(p = 0.0001\) that mean of stroke group exceeds mean of control group after adjusting for age and sex.

\(p = 0.07\)
Table 5. Mean Response Times to Visual Stimuli for Stroke Patients According to Unilateral Neglect

<table>
<thead>
<tr>
<th>Field of presentation</th>
<th>RHL With neglect (n = 22)</th>
<th>RHL Without neglect (n = 23)</th>
<th>LHL With neglect (n = 5)</th>
<th>LHL Without neglect (n = 32)</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Left</td>
<td>2.84</td>
<td>1.39</td>
<td>0.22</td>
<td>0.69</td>
<td>0.05 0.92</td>
</tr>
<tr>
<td>Central</td>
<td>2.65</td>
<td>1.76</td>
<td>1.46</td>
<td>1.72</td>
<td>1.42</td>
</tr>
<tr>
<td>Right</td>
<td>1.72</td>
<td>0.83</td>
<td>1.36</td>
<td>0.85</td>
<td>0.03 0.34</td>
</tr>
<tr>
<td></td>
<td>1.77</td>
<td>0.85</td>
<td>1.17</td>
<td>0.85</td>
<td>1.26</td>
</tr>
<tr>
<td></td>
<td>1.70</td>
<td>1.81</td>
<td>1.64</td>
<td>1.96</td>
<td>0.40</td>
</tr>
<tr>
<td></td>
<td>1.46</td>
<td>2.81</td>
<td>1.49</td>
<td>2.81</td>
<td>0.02 0.92</td>
</tr>
</tbody>
</table>

RHL, right hemisphere lesion; LHL, left hemisphere lesion; p, probability after adjustment for age and sex. Data are seconds.

0.07, respectively) that chance explained the differences.

Our findings suggest that unilateral lesions of either hemisphere result in impaired response times but that the impairment is greater among patients with RHL. We also examined whether visual hemineglect could be a factor explaining this finding. In their impaired field of attention (left), RHL patients with neglect took considerably longer to respond than those without neglect (Table 5); RHL patients with neglect also demonstrated similar delays to stimuli presented in the center. This latter finding could have considerable clinical importance given that caregivers are often counseled, when attending to stroke patients with neglect, to present visual material in the midline.

Although few LHL patients (5 of 37) had visual hemineglect (in accord with others6-7,10), when present hemineglect did not appear to influence response time (Table 5); RHL patients with neglect also demonstrated similar delays to stimuli presented in the right hemisphere (in accord with others 6-7-10), when present hemineglect may be less severe with LHL. It has also been found that the left hemisphere is not as essential for the processing of visuospatial information.6,7,10,11

The additional observation, that RHL patients without neglect did not differ from LHL patients (taken as a whole), further substantiates the need to consider the influence of visuospatial factors in the study of response time. Discrepant findings from previous response time studies on the effect of the side of the lesion2 may have arisen, in part, from the inclusion or exclusion of patients with visuospatial impairment.

We cannot be sure that the differences in response time between LHL and RHL patients were not due to differences in the size of the lesions. However, the nature of the response time task under study here permitted the inclusion of those LHL patients with disorders of comprehension and expression, and thus it is probable that even patients with large LHL were tested. The effect of the location of the lesion on response time could not be investigated because complete information was not available; CT scans had not been carried out on all patients and it was impractical and unethical to perform CT scans for the purposes of this study alone.

There are a number of limitations to our study. Not all patients could use their dominant hand. However, those at a disadvantage (LHL patients) actually performed better than those using their dominant hand (RHL patients). In normal subjects, hand use has not consistently been shown to affect response time1; nevertheless, this could pose a problem in the study of patients with hemiparesis. Our subjects may not be representative of other stroke patients: our hospital serves a primarily Jewish and suburban French Canadian population, the hospital has specific admission criteria that result in the exclusion of very mildly and very severely impaired patients, and the restraints put on therapists' time precluded the assessment of all patients.

Our results confirmed previous work in this area and provided additional observations on the role of the left and right hemispheres in response time. Of particular interest was the finding concerning the influence of visual hemineglect. Needless to say, the presence of other perceptual deficits commonly seen in conjunction with visual hemineglect18 and many other factors are likely to be implicated in response time performance. Clearly, the statement previously made by Howes and Boller2 applies: "The simple reaction time thus appears not to be so simple after all." In our opinion, the ease with which this computer program was used in our clinical setting should allow response time to be readily measured in day-to-day clinical practice. It is left to future studies to identify other determinants of response time performance and to explore its usefulness in monitoring change over time.

Acknowledgments

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References


**KEY WORDS** • cerebrovascular disorders • reaction time • visual perception
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