Attentional Abilities and Functional Outcomes Following Stroke

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Although stroke affects cognitive functioning as well as motor functioning, research on cognitive consequences has lagged behind that focused on motor function. The evidence that is accruing suggests that cognitive function is importantly related to successful rehabilitation. The present study examined two aspects of attentional functioning (divided attention and switching attention) in older adult stroke survivors and healthy older adults. In addition, the authors investigated the relation between attention and functional outcomes following stroke. Results revealed stroke-related deficits in both of the types of attention as well as significant associations between attentional functioning and both physical and social outcome measures. Poorer attentional performance was associated with a more negative impact of stroke on daily functioning. These findings suggest an important role for attention in post-stroke function and provide information that can contribute to improving outcomes following stroke.

Although stroke affects cognitive functioning as well as motor functioning, research on cognitive sequelae of stroke has lagged far behind motor function research. Recently, however, more studies of cognitive function have been carried out as part of the effort to better characterize stroke-related deficits (e.g., Hochstenbach, Mulder, Van Limbeek, Donders, & Schoonderwaldt, 1998; Kaufman et al., 1999; Rao, Jackson, & Howard, 1999). This work is critical in light of the growing evidence that cognitive function is significantly related to outcomes following stroke (e.g., Avlund & Fromholt, 1998; Bérod, Klay, Santos-Eggmann, & Paccaud, 2000; Katz, Hartman-Maeir, Ring, & Soroker, 2000; Koong, Chua, & Tow, 1998; Mysiw, Beevan, & Gatens, 1989). These studies suggest that minimizing disability following stroke will require a better understanding of cognitive abilities following stroke and their relation to stroke outcome.

Evidence is beginning to accumulate indicating that attentional function is frequently affected in stroke and may be a cognitive factor that contributes to variability in outcomes following stroke. For example, Hochstenbach and colleagues (1998) concluded from their study of cognition in stroke that attentional deficits were among the “most prominent” stroke-related cognitive changes. Marshall, Grinnell, Heisel, Newall, and Hunt (1997) reported that stroke survivors were impaired on a divided attention task relative to individuals without stroke. Rao, and colleagues (1999) reported that stroke survivors were impaired on a number of cognitive functions, including attention. Although these studies appear to be converging on a picture of stroke-related attentional deficits, each of them defines and measures attention in a slightly different way, which may lead to different conclusions regarding attentional function in stroke. Our view is that attention may be best understood as a multifaceted construct, composed of different and separable functions (e.g., McDowd & Birren, 1990). In the present work we examine a subset of these functions: divided attention and switching attention.

In addition to examining stroke-related attentional impairments, in the present study we examine the relation between attentional function and activities of daily living following stroke. Mysiw and colleagues (1989) cited the need to identify sensitive and specific measures of cognitive function in order to best predict outcomes, and we follow their lead in terms of applying measures of specific aspects of attention to the task of predicting functional outcome following stroke. Some work has been done in this area; for example, Robertson, Ridgeway, Greenfield, and Parr (1997) reported that sustained attention ability at 2 months post stroke significantly predicted functional recovery at 2 years following stroke. However, no studies have been done to examine the possible role of divided attention or attention switching ability in post-stroke outcome. The present study was designed to provide a more comprehensive investigation of attentional ability and stroke outcomes.

Sensitive and specific measures of stroke outcome are also needed. Previous studies have typically included measures restricted to basic levels of function or to disposition of the patient, such as the functional independence measure, the Barthel Index, indices of instrumental activities of daily living, or measures of length of stay in rehabilitation or discharge location (e.g., Kase et al., 1998; Sandstrom & Mokler, 1999; Suhr & Grace, 1999). However, these outcome measures fail to capture higher levels of function or the complexity of many daily life tasks for community-dwelling older adults (Duncan et al., 1999). Subtle deficits that nonetheless affect successful outcomes may be missed by these measures (e.g., Mysiw et al., 1989). The Stroke Impact
Scale (SIS; Duncan et al., 1999), a self-report questionnaire, was used in the current study to assess post-stroke outcome. The SIS is designed to capture a variety of aspects of daily life, including higher levels of functioning—domains assessed are physical function, communication, emotion, memory, and social participation. This measure has been shown to be valid and reliable (Duncan et al., 1999); the question for the present project is whether measures of basic attentional abilities will be related to these more global indices of function.

In summary, the current study had two goals: (a) to investigate the presence of deficits in divided attention and attention switching among stroke survivors relative to age-matched healthy older adults and (b) to examine the role of attentional abilities in daily life functioning of stroke survivors. We developed measures of divided attention and attention switching for use with a sample of community-dwelling stroke survivors and used the SIS to assess functional outcome. If stroke survivors have impaired attentional abilities compared with a group without stroke, then we should see group differences in performance on these tasks. If attention is related to outcome following stroke, then measures of attentional performance should be related to measures of everyday functioning.

**METHOD**

**Participants**

Fifty-five older adults with ischemic stroke and 39 healthy older adults with no history of stroke were recruited to participate in the present study. Stroke survivors were recruited from an existing registry maintained at The University of Kansas Medical Center and from local stroke support groups. Healthy older adults were recruited from an existing panel of research participants maintained by the first author. This panel is made up of community-dwelling older adults who have expressed an interest in participating in research studies.

The stroke survivors were 31 older adults whose stroke had occurred on the left side of the brain and 24 whose stroke had occurred on the right side of the brain. All stroke survivors were right-hand dominant prior to stroke. Because each participant was required to use the hand ipsilateral to the side of stroke, those with right-side stroke were able to use their dominant right hand for responding, whereas those with left-side stroke had to use their nondominant left hand. For comparison purposes, healthy older adults (all were right-hand dominant) were randomly divided into two groups: 20 were assigned to the right comparison group (responded with dominant hand), and 19 were assigned to the left comparison group (responded with nondominant hand).

**Inclusion criteria.**—To meet study inclusion criteria, participants had to be right-handed, be living independently in the community, have a Mini-Mental State Exam (MMSE; Folstein, Folstein, & McHugh, 1975) score of at least 18, have no history of brain damage (other than stroke for the stroke groups), have no history of neurological disease or depression, have sufficient use of their hand to perform the required tasks, and have normal color vision. Stroke survivors were 6 months or more post stroke. All participants were paid $40 for taking part in the present study. In addition, transportation was provided for any participant who needed or requested it.

**Demographic characteristics.**—Specific demographic information for the participant groups is given in Table 1. There were no significant differences among the groups in age ($p = .51$) or years of education ($p = .36$), nor between the stroke groups in time since stroke ($p = .63$).

**General cognitive status.**—The MMSE was administered to all participants (mean scores are shown in Table 1); overall stroke survivors achieved significantly lower scores than the comparison groups, $t(42) = 2.27, p < .03$, for the right groups; $t(48) = 2.55, p < .02$, for the left groups. No formal aphasia screening was conducted, but all participants had to correctly pass the 3-step command item from the MMSE to be included.

**Depression.**—Responses to the Geriatric Depression Scale (Brink et al., 1982; see Table 1) indicated that only 1 participant from each group scored in the depressed range (score of greater than 5), although overall stroke survivors had significantly higher depression scores than did the comparison groups, $t(42) = 2.88, p < .01$, for the right groups; $t(48) = 3.63, p < .01$, for the left groups.

**Visual acuity.**—Visual acuity was measured with the Lighthouse Near Acuity Test. All participants had acuities of 20/125 or better, which was sufficient for the current study tasks.

**Color vision.**—Ishihara’s Tests for Color Deficiency (concise edition; Ishihara, 1997) was administered to all participants. Three participants (2 stroke survivors and 1 healthy older adult) did not meet the performance criteria set by Ishihara; however, all 3 of these were able to complete the attention tasks requiring primary color perception.

**Visual perception.**—To assess visual perceptual abilities, the Motor-Free Visual Perception Test, Vertical Format (Mercier, Hebert, Colarusso, & Hammill, 1997) was administered. This test consists of 5 subtests: Matching, Constancy,

<table>
<thead>
<tr>
<th>Table 1. Demographic Information for Each Participant Group</th>
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<tbody>
<tr>
<td>Demographics</td>
</tr>
<tr>
<td>Gender (male/female)</td>
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<tr>
<td>Age</td>
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<tr>
<td>Months since stroke</td>
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<tr>
<td>Years of education</td>
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<tr>
<td>MMSE</td>
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<td>GDS</td>
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<td>MVPT</td>
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<td>Praxis</td>
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</table>

Notes: MMSE = Mini-Mental State Examination; GDS = Geriatric Depression Scale; MVPT = Motor-Free Visual Perception Test.
Memory, Closure, and Differences. Stimuli for each subtest are arranged vertically to avoid any possible confounds due to hemineglect. Mean scores on each subscale are shown in Table 1. A multivariate analysis of variance (MANOVA) revealed no effect of group on the subtest scores ($F = 1.19$, $p = .28$).

Praxis.—The Florida Apraxia Scale was administered to each participant; all older adults without stroke and all but one stroke survivor scored in the normal range (scores of 15 or higher; maximum score = 30). The average score for stroke survivors was 26.7 ($SD = 3.75$) and 27.9 ($SD = 1.79$) for healthy older adults. Although small, this difference was nearly significant by $t$ test, $t(92) = 1.93, p = .055$.

Hemineglect.—A computerized version of the Schenkenberg, Bradford, and Ajax (1980) line bisection test was used to assess spatial inattention, or neglect. A series of 12 lines of varying length was presented, one at a time, in different locations on the computer screen. A marker appeared on the far left or far right of each line (equally probable across lines within subjects), and the participant was asked to move the marker to the midpoint of the line, using the arrow keys on the computer keyboard keypad. When they were satisfied they had placed the marker at the center of the line, they pressed the “0” key on the keypad and went on to the next line. Accuracy was recorded in terms of number of pixels from true center, and errors were categorized as left errors (indicating a perceived midpoint left of true center) or right errors (indicating a perceived midpoint right of true center). Although overall errors were small, a 2 (group: stroke, control) × 2 (side: left, right) × 2 (direction: left error, right error) analysis of variance (ANOVA) revealed a main effect of group, $F(1,90) = 8.93, p < .005$, such that stroke survivors’ errors were larger ($M = 2.4$ pixels, $SD = 0.32$) than those of healthy older adults ($M = 0.95$ pixels, $SD = 0.38$). Neither side of stroke nor direction of error was a significant factor.

Dependent Measures

Attention measures.—A set of attention tasks was developed to assess switching attention and divided attention abilities in stroke survivors and healthy older adults. These tasks involved presentation of stimuli on a 15-in color computer monitor and required speeded responses using a custom response device consisting of four colored microswitches interfaced with a Pentium computer to record response times to the nearest millisecond.

Switching attention.—Two 4-choice response time tasks were developed to assess attention switching. Stimulus displays involved one, two, three, or four identical instances of one of four shape stimuli: circles, squares, triangles, or crosses. In the control single task condition, participants had to respond either to the shape of the stimuli or to the number of stimuli in a given display; a trial consisted of a 12-stimulus sequence of the single shape task and a 12-stimulus sequence of the single number task. In the alternating version of the task, the participant had to continuously alternate between responding according to the shape of the presented stimuli in one display and responding according to the number of stimuli presented in the next display. In this task version, a trial consisted of a 24-stimulus sequence presented under alternating task instructions. The task involved 3 repetitions of a combined single–alternating trial sequence.

The second attention switching task was a cued task version. In this task version, participants began a trial by performing either the shape or number task, as instructed. After a variable number of stimuli, a cue (the word shape or number) was presented on the screen simultaneously with the next stimulus, and participants were required to switch their attention to a different aspect of the display and respond on that basis. A trial began with a cue identifying the appropriate task set (shape or number) coincident with the first stimulus, followed by a variable number of stimuli (8–12), followed by the next cue to switch. The number of stimuli between switch cues was variable to reduce the temporal predictability of the switch cue. A trial was made up of three switch sequences; the entire task was comprised of 10 trials (30 switches).

Divided attention.—The divided attention task involved a 2-choice response time task and a memory task, each performed by itself and in combination with the other task. Each task was performed in response to a visual presentation of six letters, presented one at a time, in either red or green print. The letters were from the set A, B, C, D, E, F, and were presented in random order. In each series, one letter from the set was omitted and one was presented twice. The repeated letter appeared equally often in serial positions 2, 3, 4, 5, and each letter was used as the repeated letter equally often. In the single-task version of the response time task, participants simply responded as quickly as possible to the color of the letter (red or green) using two color-coded buttons on the response box. In the divided attention version of the response time task, participants were required to respond to the color of the letters while at the same time noting which of the letters in each series was repeated. In the single task version of the memory task, participants watched the series of letters as they were presented on the screen and noted which letter was repeated. In the divided attention version, they noted which letter was repeated while at the same time responding to each letter in terms of its color. In both single and divided attention task versions, participants responded orally after each series with the letter they believed had been repeated; the experimenter keyed in their response using the keyboard. Practice consisted of performing the single-task memory task until recall was perfect, three practice series of single-task response time trials, and three series of divided attention trials. In the experimental trials, participants performed alternating sets of 36 single-task and 36 dual-task trials.

Functional outcome measure.—The SIS (Duncan et al., 1999) was administered orally to each participant. The SIS is a 64-item self-report measure of functioning. Respondents indicated on a 5-point scale the level of difficulty they have had with specific activities during the previous 1 to 4 weeks. On the basis of a principal-components factor analysis on
another data set (Duncan et al., 1999), the 64 items were found to cluster into five domains: physical function, memory and thinking, emotion, communication, and social participation. Scores for each domain in the present set were calculated following the method of Duncan and colleagues (1999), using the equation: domain score = [(mean of domain items – 1) / 5-1] × 100. This equation results in domain scores ranging from 0 to 100, with 100 representing no disability.

In their work on the psychometric properties of the SIS, Duncan and colleagues (1999) reported good reliability of the scale—measures of internal consistency (Cronbach’s alpha) exceeded 0.83 and all but one intraclass correlation from test–retest data exceeded 0.70 (the correlation for the emotion domain was 0.57). In addition, validity was assessed by comparing data from each of the domains with data collected using established measures (e.g., Fugl-Meyer Motor Assessment for the Physical domain, MMSE for the Memory and Thinking domain). Good criterion validity was observed for each of the domains; correlations between the SIS and the criterion measures ranged from 0.44 to 0.84. Together, these analyses indicate that the SIS has acceptable reliability and validity for assessing stroke-related disability and function.

Procedure

Participants were part of a larger study examining attention and motor function. Each participant was tested individually in two sessions on consecutive days. Upon arrival at the laboratory on the first day, the participant was seated comfortably in a small testing room in front of a table on which the computer monitor was placed. The response box was attached to a flexible platform, which was adjusted to a comfortable location for each participant. The research assistant first oriented the participant to the project and then obtained informed consent. Following this, the SIS, the demographic measures, and an initial phase of a motor learning task (reported in a separate article; see Pohl, McDowd, Filion, Richards, & Stiers, 2001) were administered. The testing session on the first day lasted approximately 2 hours, and rest breaks were provided as needed.

On the second day the attention switching and divided attention tasks were administered, along with the second phase of the motor learning task. The order of attention tasks was counterbalanced across participants, and the motor learning task was performed last. The testing session on the second day lasted approximately 2 hours, and as before rest breaks were provided as needed.

Results and Discussion

Attention Tasks: Intertask Correlations

The tasks used in the present study were intended to assess different aspects of attentional functioning; we assumed that the different tasks measured different attentional modes or functions. To test this assumption, simple correlations were computed for each of the attention measures with each of the other measures. These correlations are shown in Table 2. As is evident in Table 2, performance measures within a task type correlated with one another, but not with measures from the other task. Thus for the present purposes, treating the attention tasks as independent is justified by these correlations.

<table>
<thead>
<tr>
<th>Attention Task</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Cued Switch RT – Pre-switch RT</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>2. (Cued Switch RT – Pre-switch RT) / Pre-switch RT</td>
<td>—</td>
<td>.95*</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
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<tr>
<td>3. Alternating RT – Single RT</td>
<td>—</td>
<td>.34* .26*</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>4. (Alternating RT – Single RT) / Single RT</td>
<td>—</td>
<td>.47* .40* .91*</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>5. Divided RT – Single RT</td>
<td>—</td>
<td>.17 .17 .08 .06</td>
<td>—</td>
<td>—</td>
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<td>—</td>
</tr>
<tr>
<td>6. Divided RT – Single RT) / Single RT</td>
<td>—</td>
<td>.01 .05 .05 .02 .89*</td>
<td>—</td>
<td>—</td>
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</tr>
</tbody>
</table>

*p < .05.

from the other task. Thus for the present purposes, treating the attention tasks as independent is justified by these correlations.

Attention Tasks: Analytic Approach

Analyses are presented separately for each of the attention tasks and the SIS. For each task, the analytic approach involved a Group (stroke, comparison) × Side (left, right) × Task Condition ANOVA. It is important to note that the side factor includes both stroke survivors and healthy older adults (i.e., left stroke survivors and left comparison group vs right stroke survivors and right comparison group). Thus any side main effects are not particularly informative about the issues addressed in the present study. In a similar vein, main effects of group typically indicate that overall, stroke survivors were slower or less accurate than the comparison group of older adults. However, in order to conclude that there are stroke-related attention deficits, significant interactions of group and side, group and condition, and group, side, and condition must be observed.

Switching Attention

Thirty-nine stroke survivors and 35 healthy adults completed the attention switching tasks. (Data from 2 stroke survivors and 2 healthy adults were lost to technical problems, 1 healthy adult was lost to fatigue, 11 stroke survivors and 1 healthy adult were unable to follow task instructions, and 3 stroke survivors failed to meet the accuracy criterion of 75% correct.) As these numbers reveal, this was a very difficult task for stroke survivors.

Alternating Task Version: Accuracy

Accuracy was defined as the proportion of correct responses (see Table 3). The only significant effect in the ANOVA was that of condition, $F(1,79) = 21.23, p < .01$; for all participant groups accuracy was higher in the single task condition ($M = .97$) than in the alternating task condition ($M = .92$). Thus among those adults who were able to perform the alternating attention task, accuracy did not differ as a function of group.

Alternating Task Version: Response Time

Means of correct median response times were calculated for each participant group and task condition; these data are displayed in Figure 1. The ANOVA revealed main effects of group, $F(1,71) = 16.28, p < .001$, and condition, $F(1,71) =$
169.20, p < .001; stroke survivors responded more slowly than healthy older adults, and all responses were slower in the alternating task than the single task. In addition, there was a significant interaction of group and condition, $F(1,71) = 7.07, p = .01$, indicating that the slowing in the alternating task relative to the single task was greater for stroke survivors than for healthy older adults. This finding suggests that alternating attention is more challenging and requires more time for stroke survivors than for healthy older adults.

Because of baseline differences in response time between the stroke and comparison groups, a second analysis was carried out using a proportion slowing score as a way of controlling for the possible confounding effect of baseline differences. A proportion slowing score \( \left( \frac{\text{alternating response time}}{\text{single task response time}} \right) / \text{single task response time} \) was calculated for each participant (mean scores are shown in Table 3), and these scores were subjected to a 2 (group: stroke, comparison) $\times$ 2 (side: left, right) ANOVA. In analyses of proportion scores, a statistically significant main effect of group would indicate a stroke-related deficit. The ANOVA did reveal a main effect of group, $F(1,70) = 4.17, p < .05$, indicating a smaller cost of switching for the comparison group than for the stroke survivors. This main effect was qualified by a significant interaction of group and side, $F(1,70) = 4.02, p < .05$; the two right groups did not differ from one another ($M = .33$ and .34 for right comparison and stroke survivors, respectively), whereas the left stroke survivors incurred significantly greater switching costs ($M = .52$) than did the left comparison group ($M = .32$). In this analysis using a more conservative measure of the “costs” of alternating attention, it was shown that only individuals with left-side stroke incurred greater costs than the comparison group; individuals with right-side stroke did not differ from their comparison group.

### Cued Task Version: Accuracy

Accuracy was defined as the proportion of correct responses (see Table 3). The only significant effect was that of group, $F(1,70) = 4.23, p < .04$; accuracy among healthy older adults ($M = 93.4\%$) was higher than that among stroke survivors ($M = 90.1\%$). Because a group difference in accuracy was observed here but not in the alternating task version, it appears that cued attention switching was more difficult for stroke survivors than the alternating task version, though overall accuracy levels are quite high.

### Cued Task Version: Response Time

Response times were sorted into groups of trials according to their proximity to the switch cue. That is, the median of the three trials just prior to the switch cue was calculated for each participant and is referred to as the preswitch condition. The median of the three trials just after the switch cue was calculated for each participant and is referred to as the switch condition. Means of correct median response

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**Table 3. Means and Standard Deviations for Each of the Attention Measures, by Group**

<table>
<thead>
<tr>
<th>Measure</th>
<th>Right Stroke</th>
<th>Right Control</th>
<th>Left Stroke</th>
<th>Left Control</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>$M$</td>
<td>$SD$</td>
<td>$M$</td>
<td>$SD$</td>
</tr>
<tr>
<td><strong>Switching</strong></td>
<td></td>
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<td></td>
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<tr>
<td>Alternating Task</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Single task accuracy</td>
<td>97.3</td>
<td>3</td>
<td>98.0</td>
<td>2</td>
</tr>
<tr>
<td>Alternating task accuracy</td>
<td>92.6</td>
<td>8</td>
<td>95.6</td>
<td>6</td>
</tr>
<tr>
<td>Single task RT</td>
<td>1255</td>
<td>343</td>
<td>1033</td>
<td>224</td>
</tr>
<tr>
<td>Alternating task RT</td>
<td>1677</td>
<td>492</td>
<td>1384</td>
<td>365</td>
</tr>
<tr>
<td>Proportion slowing</td>
<td>.34</td>
<td>.18</td>
<td>.33</td>
<td>.13</td>
</tr>
<tr>
<td><strong>Cued Task</strong></td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td>Memory Task</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Memory accuracy</td>
<td>70.9</td>
<td>16</td>
<td>82.0</td>
<td>10</td>
</tr>
<tr>
<td><strong>Red-Green Task</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Single task accuracy</td>
<td>97.9</td>
<td>2</td>
<td>98.1</td>
<td>2</td>
</tr>
<tr>
<td>Divided attention accuracy</td>
<td>96.7</td>
<td>3</td>
<td>96.8</td>
<td>3</td>
</tr>
<tr>
<td>Single task RT</td>
<td>724</td>
<td>232</td>
<td>610</td>
<td>124</td>
</tr>
<tr>
<td>Divided attention RT</td>
<td>1175</td>
<td>318</td>
<td>991</td>
<td>208</td>
</tr>
</tbody>
</table>

**Note:** RT = response time.
times were calculated for each participant group and task condition and are shown in Table 3 and Figure 2. The main effect of group was significant, $F(1,71) = 13.44, p < .001$, indicating that stroke survivors responded more slowly than did healthy older adults. The main effect of condition was also significant, $F(1,71) = 76.14, p < .001$, indicating that response times were slower in the switch condition than the pre-switch condition. Although the pattern of results suggests that stroke survivors are more slowed than healthy older adults by the requirement to switch attention, the interaction of group and condition was not significant, $F(1,71) = 3.01, p < .09$. Two factors complicate the interpretation of these findings. The first is power; 14 participants from the stroke survivor group were not able to perform these tasks for reasons other than technical difficulties, significantly reducing our sample size and thus also reducing our power to detect group differences. In addition, it is possible that the obtained data underestimate true differences that may characterize the groups, because we have no data from those who found the task too difficult to complete.

**Divided Attention**

Thirty-seven healthy older adults and 47 stroke survivors completed the divided attention task. (Data from 1 stroke survivor and 1 healthy adult were lost to fatigue, 2 stroke survivors could not complete the task because they reported poor ability to distinguish red and green, and 5 stroke survivors and 1 healthy adult were unable to follow task instructions.)

**Memory Task Accuracy**

Participants practiced the memory task by itself and demonstrated that they could perform it without error. Under divided attention conditions, performance was less than perfect; mean accuracy levels are shown in Table 3 and Figure 2. The ANOVA on these data revealed only one significant effect, a main effect of group, $F(1,80) = 10.80, p < .001$, indicating that stroke survivors were less accurate in reporting the repeated letter under dual task conditions than were healthy adults. Because every participant could accurately report the repeated letter under single task conditions, the present findings indicate a divided attention deficit for stroke survivors; the requirement to divide attention affected stroke survivors more negatively than it did the comparison groups without stroke.

**2-Choice (Red–Green) Task Response Time**

Means of correct median response times were calculated for each participant group and task condition and are shown in Figure 3. The main effect of group was significant, $F(1,80) = 22.34, p < .001$, indicating that overall, stroke survivors were slower to respond than were healthy older adults. The main effect of condition was also significant, $F(1,80) = 402.07, p < .001$, indicating that response times were faster in the single task condition than in the dual task condition. The interaction of group and condition was not significant ($F < 1.0$). Thus on this component of the divided attention task there was no indication that stroke survivors performed any differently than those without stroke. However, interpreting divided attention ability requires that both tasks between which attention was to be divided be considered. Although those with and without stroke did not differ on the red–green task in either speed or accuracy, the memory task did produce group differences. It may be that stroke survivors gave greater emphasis to the response time task than to the memory task, and so were able to maintain performance in the former but not the latter.

**2-Choice (Red–Green) Task Accuracy**

The only significant effect in the proportion correct data (see Table 3) was that of condition, $F(1,85) = 16.44, p < .001$; although absolute differences were small, accuracy was higher under single task conditions ($M = .98$) than under dual task conditions ($M = .96$). Although accuracy on the memory task differed between participant groups, accuracy on the red–green response time task did not differ between groups.

**Stroke Impact Scale**

SIS domain scores can range from 0 to 100, with 100 representing the highest level of functioning. Mean domain scores for each participant group are shown in Table 4. As expected, healthy older adults reported higher levels of functioning than stroke survivors in each domain. A one-way MANOVA was carried out to assess these group differences in SIS scores. A significant difference was observed between the two participant groups on the domain scores, Wilks’ $\Lambda = .62, F(5,87) = 10.66, p < .001$. Follow-up univariate ANOVAs were conducted for each of the domain scores; using the Bonferroni method, each ANOVA was tested at the .01 level. Significant group differences indicating lower levels
of functioning were obtained on all domains (all \( p < .01 \)) except the communication domain (\( p < .04 \)).

**Correlations Between SIS and Attention Measures: Stroke Survivors**

Simple correlations were calculated between the attention measures and the domains of the SIS for stroke survivors. The attention measure for the divided attention memory task was accuracy in the divided attention condition. The attention measure for the remaining tasks was the difference in response time between the control condition and the attention-demanding condition; this difference can be described as a measure of the cost of performing the attention demanding task. Our predictions were for positive correlations between the SIS variables and the divided attention memory task (greater accuracy associated with higher SIS scores) and negative correlations between the SIS variables and the other attention tasks (greater RT cost associated with lower SIS scores). The pattern of correlations shown in Table 5 indicates that most of the correlations are in the predicted direction and that at least one index of each of the attention abilities was correlated with an aspect of self-rated functioning as indicated by the SIS. Specifically, self-rated physical functioning and self-rated memory function were related to performance in the divided attention memory task. Of particular interest was the finding that self-rated social participation was related to indices representing both divided attention and attention switching ability. Self-rated functioning on the Emotion subscale and the Communication subscale was not related to any of the attention measures.

**Participant Attrition**

Nineteen stroke survivors who began the present task battery were unable to complete at least one of the attention tasks for reasons other than technical difficulties (specific reasons such as inability to follow directions or fatigue are given for each task in the Results section). One outcome of this attrition is that the present findings may underestimate true stroke-related deficits if those who failed to complete each task were the less-able participants. Although it is not possible to evaluate this hypothesis directly, some of the data from the present study can be brought to bear on the question. Because every participant provided demographic information, some post hoc analyses on these data make it possible to investigate differences between those who completed all tasks and those who did not. A grouping variable was created to separate stroke survivor participants who failed to complete at least one of tasks for other than technical reasons (incomplete data group) from those who completed all the tasks (complete data group). (No analyses were carried out on the healthy older adults as only 5 individuals in that group failed to complete all of the tasks.)

With regard to demographic data, those who completed every task were significantly younger (\( M = 69.1 \) years) than those who did not complete every task (\( M = 73.8 \), \( t(44) = 2.55, p < .02 \), and scored significantly higher (\( M = 28.0 \)) on the MMSE than those who did not complete every task (\( M = 24.8 \), \( t(44) = 4.17, p < .01 \)). These MMSE data support the hypothesis that those who were more cognitively impaired were less able to complete the present task battery. This finding suggests that our results may underestimate the severity of cognitive deficits experienced by stroke survivors, as well as underestimate the relation between these deficits and functional performance.

**General Discussion**

The present study was undertaken with two goals: (a) to investigate the presence of attentional deficits among stroke survivors relative to age-matched healthy older adults and (b) to examine the role of attentional abilities in daily life functioning of stroke survivors. With regard to the first goal, we did observe stroke-related attentional deficits; overall,
stroke survivors were slower and performed less well than the comparison group on some aspect (e.g., speed, accuracy, or both) of both types of attention measured. In addition, many more stroke survivors than healthy older adults were unable to complete all of the tasks, suggesting that our data may underestimate actual stroke-related deficits.

Our findings based on the more conservative proportional attention costs can be summarized as follows: Individuals with left stroke performed less well than the healthy comparison group on a task requiring the rapid switch of attention back and forth between different response sets, and stroke survivors in general performed less well than the healthy comparison group on a memory task when attention was divided. These findings that stroke survivors have some difficulty with divided attention and attention switching are consistent with other work showing stroke-related attention deficits (Marshall et al., 1997; Robertson et al., 1997; Sturm & Willmes, 1991). Stroke-related cognitive deficits were evident in the present study even though the participant sample had near normal MMSE scores and were considered highly recovered. These findings support the notion that specific and sensitive measures are required to fully characterize cognitive function in stroke survivors. A similar point was made a number of years ago by Mysiw and colleagues (1989). They assessed a variety of cognitive domains (orientation and attention, language, spatial constructions, memory, calculations, and reasoning) in an effort to characterize stroke-related cognitive deficits more specifically than had been possible with global measures such as the MMS. The approach used in the present study was to produce a fine-grained analysis of just one aspect of cognitive function by operationalizing the concept of attention in terms of separate modes (e.g., divided, switching) that can be separately measured. This approach revealed significant stroke-related deficits on both of these attentional modes, as well as significant associations between these abilities and daily function as measured by the SIS. These findings suggest an important role for attention in post-stroke function, and perhaps even in predicting stroke recovery.

Associations between attentional abilities and daily life functioning in stroke survivors were documented in the present study using the SIS. It is important to note, however, that the SIS is a self-report measure, subject to the limitations inherent in self-report such as inaccurate perceptions of ability. Thus the present work could be strengthened by replication with additional performance-based measures of everyday functioning. Nonetheless, in other work the SIS has been shown to have good validity against standard objective measures of functioning (Duncan et al., 1999) and the present findings are in line with other work indicating that intact attentional abilities are related to successful outcomes following stroke. For example, Robertson and colleagues (1997) reported that sustained attention ability measured 2 months following stroke significantly predicted functional status in individuals 2 years post stroke.

In the present study, aspects of both divided and switching attention were impaired in stroke, and both were related to social participation. Social participation requires one to engage in a succession of tasks and response sets and to process multiple simultaneous demands (as in conversation and activity that flows from one topic to another). As the data from the present study indicate, if the ability to respond to such demands is impaired, participation will suffer. It is also interesting to note in these data that attention was related to both physical function and social participation, suggesting that the role of attentional abilities in daily function may be quite far-reaching.

These findings that even subtle attention impairments are related to decreased function in some domains indicate that attentional processing skills may need to be addressed specifically in post-stroke rehabilitation. A thorough evaluation of attentional ability may be warranted at the beginning of rehabilitation efforts, even in individuals who appear to be cognitively intact. In this way intervention programs could be tailored to account for existing deficits that may interfere with the ability to maximally benefit from rehabilitation efforts. This is particularly important because physical rehabilitation efforts to restore function and minimize disability after stroke depend largely on the person acquiring new motor skills or learning new ways of performing old skills. Motor performance is known to be adversely affected by increased attentional demands (Tipper, Lortie, & Baylis, 1992). Further, attention is a key cognitive component in learning new motor skills, particularly in the early stages of learning (Schmidt, 1988). It has been shown that age-related attentional deficits interfere with the performance of motor skills (Chen et al., 1996). To the extent that attentional deficits can be minimized, positive rehabilitation outcomes may be maximized.

One way to improve intervention outcomes may be to provide the stroke survivor with attention training. There is some evidence from studies of individuals with traumatic brain injury that practice on tasks requiring a variety of attention mechanisms improves performance on attention tasks (Nieman, Ruff, & Baser, 1990; Sohlberg & Mateer, 1987). There is also preliminary evidence that attention training post-stroke can improve attentional processing as well (Robertson, Tegner, Tham, & Nimmo-Smith, 1995; Sturm & Willmes, 1991). In light of the present findings, attention training may be expected to improve some functional outcomes.

A second possibility for improving post-stroke intervention is to alter how it is delivered. Perhaps extra cues to assist the person in appropriately allocating attention, such as an explicit emphasis on the key element of each portion of the training session, and explicit instructions and a pause before switching to a new element of an activity would allow the stroke survivor to maximize the benefits that rehabilitation programs provide. Other possible modifications to intervention delivery methods in light of the present data include practicing new skills initially in a nondistracting environment to minimize attentional demands, providing practice of single skills prior to requiring the organization of several simultaneous skills, and limiting practice to only a few skill elements in a single treatment session. Of course, whether such approaches do facilitate more positive outcomes must await further empirical testing.

Thus for the present much work remains to be done. For example, the investigation reported here examined only a limited set of attentional tasks; future studies might look at
modality effects, response mode effects, or task complexity effects to fill out the picture of attentional functioning following stroke. Future studies might also examine the relation between changes in attentional ability and changes in function to increase confidence in the significance of the association observed in the present study. The present findings also need to be generalized to a wider range of severity among stroke survivors. In addition, if assessment of attentional function is to be useful to the rehabilitation professional, simpler measures will need to be developed that can be useful in clinical contexts. Even in light of these considerations, the present data indicate that pursuing this line of research will likely be important for understanding stroke-related deficits and for improving outcome following stroke.

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REFERENCES


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