Attention Deficits After Incident Stroke in the Acute Period: Frequency Across Types of Attention and Relationships to Patient Characteristics and Functional Outcomes

Suzanne L. Barker-Collo,[1] Valery L. Feigin,[2] Carlene M. M. Lawes,[3] Varsha Parag,[3] and Hugh Senior[4]

[1]Department of Psychology, University of Auckland, Auckland, New Zealand; [2]National Research Centre for Stroke, Neuroscience and NeuroRehabilitation, Auckland University of Technology, Auckland, New Zealand; [3]Clinical Trials Research Unit, School of Population Health, University of Auckland, Auckland, New Zealand; [4] School of Medicine, University of Queensland, Brisbane, Australia

Background: Attention deficits are common post stroke and result in poorer functional outcomes. This study examined the frequency of attention deficits after incident stroke and their correlates. **Method:** Attention of 94 stroke survivors was assessed using the Bells test, Trails Making Test A/B, 2.4- and 2.0-second trials of the Paced Auditory Serial Addition Test (PASAT), and Integrated Auditory Visual Continuous Performance Test (IVA-CPT) within 3 weeks post stroke. Wider functioning was assessed using the Medical Short Form-36 (SF-36) Physical and Mental Component Summary scores (PCS and MCS), London Handicap Scale, Modified Rankin Scale, General Health Questionnaire-28, and Cognitive Failures Questionnaire (CFQ). **Results:** Most participants were impaired or very impaired on the IVA-CPT (*z* scores > 3 *SD*s below normative mean) but not other attention measures. Functional independence and cognitive screening test (Mini-Mental State Examination) performance were significantly related to IVA-CPT, Trails A/B, and Bells tests but not PASAT. Better performance across the Bells test was related to better SF-36 PCS, whereas Trails A and the PASAT were related to SF-36 MCS. Better CFQ naming was related to Trails B, whereas worse CFQ memory was related to better PASAT performance. **Conclusion:** Attention deficits are common post stroke, though frequency varies widely across the forms of attention assessed, with tests of neglect and speeded attention tasks being linked to quality of life. This variability of performance and linking to wider outcomes suggests the need for comprehensive assessment of attention and that attention is a viable target for rehabilitative efforts. **Key words**: *attention, functional outcomes, incident stroke*

Neuropsychological test batteries reveal that attention is a primary area of poststroke cognitive deficits, with these deficits being particularly common after right hemisphere lesion.[1] In 168 stroke survivors,[2] 31.3% of individuals experienced visual inattention, with 39.1% having wider executive dysfunction (ie, cognitive flexibility and Test of Everyday Attention), leading to an estimate of 31% to 35% of stroke survivors experiencing attention deficits. A 2-year noninterventionist stroke longitudinal study[3] concluded that attention deficits were the most prominent neuropsychological changes, improving on average by only 7% in persons with left-hemisphere brain lesions and 28% in those with right-hemisphere brain damage. In studies comparing stroke survivors without dementia with age-matched controls and patients with Alzheimer's disease (AD), severity of attention deficits was similar for stroke and AD groups, although stroke patients had fewer impairments of memory.[4,5] Stroke survivors also have impaired divided attention relative to controls.[6] When divided and switching attention and their relationship to daily living (Stroke Impact Scale) were examined in 55 ischemic stroke survivors and 39 healthy controls who did not differ significantly in age, gender, or education, community stroke survivors experienced significant attention deficits.[7]

Broadbent[8] presented the first comprehensive model of attention as a single-filter, limited-capacity, information-processing framework in which only 1 stimulus could be attended to at a time. This theory was modified in Treisman's[9,10] 2-channel model of selective attention in which nonattended stimuli are

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not completely filtered out but attenuated according to their subjective importance. Subsequent theories[11,12] suggest that all stimuli are analyzed with further processing of pertinent stimuli just before entry into longer lasting memory, effectively placing the locus of the bottleneck later in the process continuum. Kahneman[13] argued for a finite cognitive capacity to devote to tasks; the number of activities that can be performed is determined by the capacity each requires, which is controlled by a "central processor" that adjusts and allocates attention accordingly. It was Allport's[14] model that provided a theoretical basis for divided attention, arguing for several separate modules for different kinds of input. Similarly, Baddeley and Hitch's[15] model of working memory included a "central executive" that is primarily attentional in nature and responsible for directing attention to and from a phonological loop (verbal stimuli) and a visuospatial sketchpad (visuospatial stimuli); this model was later expanded to include a third system, the episodic buffer.[16] Brain imaging has provided a functional anatomy of the human attention system, and most researchers now conceive it as a system in which sequential processing occurs in stages using different brain systems.[17]

Clinical models of attention differ from investigative models. One of the most commonly used models for the clinical assessment and remediation of attention deficit is Sohlberg and Mateer's[18] hierarchical model of attention, which is based on the recovery of attention processes of individuals with brain injury after coma. In this model, attention is not a unitary entity but includes perceiving individual items (focused attention), concentrating (sustained attention), avoiding distractions (selective attention), shifting focus (alternating attention), and responding to multiple tasks simultaneously (divided attention). These various aspects of attention are assessed using a combination of measures, such as Continuous Performance Tests (sustained, selective, alternating attention), cancellation tasks (focused attention, neglect), and tasks such as the Trail Making Test A and B[19] and the Paced Auditory Serial Addition Test (PASAT[20]; alternating, divided attention). Thus, in rehabilitation, comprehensive assessment is required to determine what form(s) of attention deficit are present as even small attention deficits have been linked to poorer functional outcomes. For example, distractibility and poor selective attention are reportedly common in acute hospitalized stroke patients and are associated with impaired balance and functional impairment,[21] suggesting selective and divided attention should be a focus of stroke rehabilitation. Sustained attention at 2 months post stroke significantly predicts functional recovery 2 years post stroke.[22] Also, attention is a key component in learning new skills, particularly in the early stages of learning,[23] which makes it particularly relevant to successful rehabilitation. Thus, it is not surprising that the American Heart Association[24] endorsed recommendations for early identification and rehabilitation of attention deficits in stroke patients.

The purposes of this study were (1) to identify the frequency of various forms of attention deficit (both visual and auditory) after first-ever stroke, which might then be targeted for rehabilitation; (2) to identify characteristics (ie, demographics, stroke characteristics, poststroke functioning) associated with greater likelihood of attention deficits; and (3) to examine relationships between measures of attention and measures of disability, handicap, and health-related quality of life. To achieve these aims, we used a battery of tests and a wide range of functional outcome measures that assess the various aspects of attention (ie, Continuous Performance Test [auditory and visual sustained, selective, alternating attention], cancellation task [visual focused attention/neglect], Trail Making Test A [visual sustained attention] and B [visual alternating and divided attention], and the PASAT [auditory alternating and divided attention]).

Method

Participants

Participants were 94 survivors of first-ever ischemic stroke or primary intracerebral hemorrhage consecutively admitted to 2 hospitals in Auckland, New Zealand, over 18 months. Individuals were excluded if they were unable to give informed consent; experienced severe cognitive deficits precluding participation (Mini-Mental State Examination [MMSE] < 20); were not medically stable (eg, heart failure); were not fluent in English, as standardized administration of tests requires English fluency; or had another

condition that could impact results (eg, drug/alcohol abuse, significant aphasia or hemiparesis). Eligible stroke survivors were approached within 3 weeks after stroke onset (mean = 17.9 days, *SD* = 10.05). All participants provided written informed consent, and the study was approved by the regional ethics committee. Participants included all those individuals who completed initial screening for potential attention deficit as part of a randomized clinical trial of cognitive rehabilitation for attention.[25] As seen in **Table 1**, the sample was roughly half male and half female, with the majority being married, of European ethnicity, and right handed. The majority of strokes were ischemic, with slightly more having occurred within the left hemisphere. Mean score on the Barthel Index[26] indicated a group of patients with a relatively high level of independence in performing activities of daily living.

Table 1. Demographic and stroke characteristics of participants

Characteristic	N = 94
Age, mean (*SD*), years	68.22 (15.65)
Gender, n (%)	
Male	54 (57.4)
Female	40 (42.6)
Ethnicity, n (%)	
European	58 (61.7)
Māori	11 (11.7)
Pacific Island	7 (7.5)
Indian	2 (2.1)
Marital status, n (%)	
Married	57 (60.6)
Single	21 (22.3)
Separated/divorced	3 (3.2)
Widowed	13 (13.8)
Handedness, n (%)	
Left	8 (8.5)
Right	86 (91.5)
Education, n (%)	
Primary	10 (10.6)
Secondary	54 (57.4)
College	13 (13.8)
University	17 (18.1)
Barthel Index, mean (*SD*)	14.62 (5.68)
MMSE, mean (*SD*)	26.85 (2.59)
Stroke type, n (%)	
Ischemic	82 (87.2)
TACS	8 (9.8)
PACS	34 (51.2)
LACS	11 (13.4)
POCS	7 (8.5)
Uncertain	22 (26.8)
Intracerebral haemorrhage	6 (6.4)
Subarrachnoid haemorrhage	2 (2.1)
Uncertain	4 (4.3)
Hemisphere of lesion, n (%)	
Left	46 (50.5)
Right	41 (45.1)
Other	4 (4.4)
Days post stroke, mean (*SD*)	17.99 (10.05)

Note: MMSE = Mini-Mental State Examination; TACS = total anterior circulation stroke; PACS = partial anterior circulation stroke, LACS = lacunar stroke, POCS = posterior circulation stroke.

Measures

Bells test

The Bells test[27] consists of an A4-sized paper divided into 7 vertical sections, each containing 35 distracter figures (eg, birds, key, car) and 5 target figures (bells). All figures are solid black silhouettes. The participant is presented with a practice sheet in which a single bell is presented in the center, surrounded by 14 distracters, and is asked to name each object. The examiner then presents the test sheet and asks the participant to circle all the bells he or she can find. If the participant stops before all the bells are circled, he or she is asked to check the work. The scores received for this test are the total number of omissions in the 3 left sections versus the center and the 3 right sections. More than 3 missing bells has been associated with presence of deficit. The Bells test is reported to be more sensitive to neglect in stroke patients than other cancellation tasks.[28]

Integrated Visual Auditory Continuous Performance Test

The Integrated Visual Auditory Continuous Performance Test[29] (IVA-CPT) is a computerized assessment in which examinees press a button when they see or hear a "1" (target) and do not press when they see or hear a "2" (foil). After a warm-up and 32 practice items, the test has 500 trials and lasts for approximately 13 minutes. Equal numbers of auditory and visual stimuli are presented in a pseudorandom order. As a measure of attention, vigilance scores indicate

errors of omission, with separate quotient scores for visual, auditory, and full-scale attention. IVA-CPT scores are calculated as quotient scores that have a mean of 100 and a standard deviation of 15. This task has been used to monitor treatment-related changes in attention post stroke.[25] The IVA-CPT also includes an index of persistence, which is described as a measure of motivation when the test taker is asked to do "one more thing." In addition to reduced motivation, poor scores on this index can reflect motor or mental fatigue.

Trails A and Trails B[19,28]

Trail Making Tests A and B assess mental flexibility, attention, and speed with a motor component, taking 5 to 10 minutes to administer.[30] Trails A requires the participant to connect numbered circles in order as quickly as possible and requires visual sustained attention.[31] Errors are immediately corrected by the experimenter, and participants are told to resume from where they made the mistake. In Trails B, there are circled numbers and letters on the page, and the participant must alternate connecting numbers and letters (ie, 1-A-2-B-3-C, etc), which requires that attention be divided and alternating. Performance is measured as the time in seconds taken to complete each task. Raw scores are converted to standard scores using available normative data.[28] Trails B shows good construct validity in its relationship with other timed executive dysfunction tests. Interrater reliability has been reported to be 0.94 for Trails A and 0.90 for Trails B.[30] This test is commonly used in studies of cognition post stroke[32] and has been recommended by the National Institute of Neurological Disorders and Stroke harmonization standards.[33]

Paced Auditory Serial Addition Test

The PASAT[20] is an audio-taped task that presents participants with a list of 61 single-digit numbers. Participants must add each number to the preceding number and state their answer. Over trials, speed of presentation increases. Only the 2 slowest trials were administered in this study (2.4-second interstimulus interval [ISI] and 2.0-second ISI). Performance is the total number of correct responses produced, with standard scores calculated based on age-adjusted normative data. It was selected so that assessment of auditory attention need not be solely reliant on the auditory index of the IVA-CPT. Lezak[17(p365)] reported that, despite being a difficult and stressful test, "it can be useful for those patients whose subtle attentional deficits need to be made obvious." As with most neuropsychological tests, the PASAT requires multiple abilities with factor-analytic studies, indicating that it is more related to speed of processing and attention than to memory, visuoconstruction, or verbal ability.[34] All administration and scoring were conducted according to standardized procedures. The PASAT is a commonly used task within clinical populations, including stroke.[35]

Barthel Index

The 10-item Barthel Index[36] rates an individual's ability to engage in independent activities of daily living (eg, feeding, bathing, dressing). Scores range from 0 to 100, with higher scores indicating higher levels of independence. It is widely used in stroke populations; it has high levels of reliability[37,38] and is a good predictor of stroke outcome and reflection of overall stroke severity.[39]

Mini-Mental State Examination

The MMSE[40] is a 30-point questionnaire used to screen for cognitive impairment. It is also used to estimate the severity of cognitive impairment at a given time and to follow the course of cognitive changes in an individual over time. The MMSE includes orientation to self and to the time and place of the test, repeating lists of words, arithmetics such as the serial 7s, language use and comprehension, and basic motor skills (eg, copy 2 pentagons). Lower scores indicate greater cognitive impairment.

Medical Short Form-36

The Medical Short Form-36[41] (SF-36) was used to assess self-rated physical and mental

health components of health-related quality of life (HRQoL), as measured by the Physical Component Summary (PCS) score and Mental Component Summary (MCS) score. This is a standard measure of HRQoL in stroke patients.[42–44] The SF-36 has been tested for validity and reliability across various populations,[45,46] including stroke patients[43,47] and ethnic groups such as Māori, Pacific Island peoples, and New Zealand Europeans.[48,49] The SF-36 comprises 36 self-rated items organized into 8 scales, with each scale scored out of 100 points. These have been standardized to have a mean of 50 and standard deviation of 10.[41] Higher scores are associated with better HRQoL.

London Handicap Scale

The London Handicap Scale[50] (LHS) has been well validated in stroke survivors[51,52] and covers all of the domains of the World Health Organization's definition of handicap (mobility, physical independence, occupation, social integration, orientation, and economic self-sufficiency). Each of these 6 areas is classified on a 6-point scale ranging from 0 (*maximum handicap*) to 5 (*no handicap*). Overall scores above 15 indicate no, slight, or moderate handicap and those below 15 indicate considerable, severe, or extreme handicap.[53] The test-retest reliability coefficient for the LHS is 0.91.[50]

Modified Rankin Scale

Level of disability or independence in activities of daily living was evaluated by the Modified Rankin Scale (MRS).[54] The MRS defines 6 levels of disability, with level 6 being death and level 0 reflecting independence/no disability.[55,56] Although the MRS is highly correlated with other commonly used measurements of poststroke disability such as the Barthel Index and FIM,* individual scores in the MRS describe clinically distinct functional states of the patients and, therefore, have some advantage over these measurements.[26] Good outcome is usually defined as MRS <3 and poor outcome as 3–6.[57]

*FIM™ is a trademark of Uniform Data System for Medical Rehabilitation, a division of UB Foundation Activities, Inc.

General Health Questionnaire-28

The General Health Questionnaire-28[58] (GHQ-28) is a well-established and validated measure of psychological morbidity in various patient groups, including persons with stroke, stroke caregivers, and general practice populations.[58–60] Sensitivity and specificity of the self-rated GHQ-28 (0.7 and 0.8, respectively) are satisfactory,[58,61,62] and its scores correlate well with the standard psychiatric diagnostic assessment measures.[63,64] The GHQ-28 has 4 subscales measuring somatic symptoms, anxiety and insomnia, social dysfunction, and severe depression (including suicidal ideation). It has been validated in New Zealand women.[65] The GHQ-28 will be considered, in addition to the SF-36, because of its inclusion of a depression subscale. Individuals with poststroke depression exhibit significantly more neuropsychological impairment than their nondepressed counterparts when matched on size and location of lesion.[66]

Cognitive Failures Questionnaire

The Cognitive Failure Questionnaire[67] (CFQ) is a 25-item, self-report assessment of everyday difficulties related to cognition across 4 areas: memory, naming, concentration, and blunders.[68,69] The frequency with which each item (eg, Do you drop things? Do you find you forget people's names?) occurs is rated from 0 (*never*) to 4 (*very often*). Ratings on this questionnaire remain relatively stable over time and are highly correlated to ratings from significant others,[67] and it is commonly used to assess daily cognition poststroke.[35,70]

Procedure

Participants were approached within 3 weeks post stroke, at which time the study was explained to them and initial inclusion/exclusion criteria were reviewed to determine eligibility. Those participants eligible for inclusion in the main trial[25] who consented to participate in the study then had an individual assessment session scheduled. Only baseline assessment data were included in analyses for this article. Baseline assessments were conducted in bookable rooms within the hospital

or in the participant's place of residence if he or she had been discharged. Only 1 participant was still a resident in a poststroke rehabilitation facility at the time of assessment. All assessments were conducted within 1 week of initial contact with the participant. All cognitive assessments were conducted by a trained neuropsychologist and were administered and scored according to standard procedures. On the IVA-CPT index of persistence (measures motivation and can reflect motor or mental fatigue), all participants' scores were within 1 standard deviation of the normative mean, indicating adequate motivation to perform well.

Results

In following directly from the 3 aims of this study, we present the results in 3 sections. First, we present performance across attention measures to identify the frequency of various forms of attention deficit (both visual and auditory) after first-ever stroke. Second, we use correlation analyses to determine whether participant and stroke characteristics (ie, demographics, stroke characteristics, poststroke functioning) are associated with greater likelihood of attention deficits. Finally, we use further correlation analyses to examine relationships between measures of attention and measures of disability, handicap, and HRQoL.

Frequency of attention deficits

Table 2 presents performance of the sample across measures of attention, both as mean performance and as the proportion of individuals whose *z* scores fell in particular ranges. These are discussed in terms of auditory attention, visual attention, and visual neglect tasks.

Auditory attention

As seen in **Table 2**, more than 50% of participants produced impaired or very impaired scores on the IVA-CPT indices of auditory attention, producing mean *z* scores falling more than 3 *SD*s below the normative mean. Mean *z* scores for 2.4-second and 2.0-second pacing PASAT trials fell 1 to 2 *SD*s below the normative mean, with the mean number correct per trial being 25.47 (*SD* = 10.83) and 22.20 (*SD* = 12.33), respectively. The greatest proportion of participants (52.9%) performed within the average range on the 2.0-second trial and the below-average range (54.9%) on the 2.4-second trial. A number of participants were too cognitively impaired to complete the PASAT, which may have elevated the resulting scores.

Visual attention

As seen in **Table 2**, more than 50% of participants produced impaired or very impaired scores on the IVA-CPT indices of visual attention, producing mean *z* scores falling more than 3 *SD*s below the normative mean, which is consistent with performance on the IVA-CPT auditory attention index. In contrast, mean *z* scores Trails A and B scores were slightly better, falling 2 to 3 *SD*s below the normative mean, with mean raw scores of 92.28 seconds (*SD* = 91.68) and 212.54 seconds (*SD* = 158.78), respectively. On Trails A and B the greatest proportion of participants performed within the average range, and a smaller but still large proportion of participants (26%–28%) performed in the very impaired range.

Visual neglect

On the Bells test, most participants did not miss any stimuli in any portion of the test. With the applying standard criteria of ≥3 bells omitted, 24.2% of participants experienced left visual inattention, 14.3% experienced right visual inattention, and 2% experienced both left and right visual inattention.

Relationship of attention to demographics, stroke site, or overall functioning

To examine relationships between demographic and stroke characteristics and attention, we conducted a 2 × 2 × 3 multivariate analysis of variance with gender, hemisphere of stroke (left, right), and ethnicity (European, Māori, other) as grouping variables and performance on measures of attention as dependent variables. Note that ethnic groupings were small, and therefore conclusions drawn from the findings must be viewed with caution. Bonferroni correction was

Table 2. Performance across attention measures as group mean performance and proportion of *z* scores falling within particular ranges

			% within each *z* score range						
Measure	**N**	**Mean (*SD*)**	**<–3 Very impaired**	**≥–3 and <–2 Impaired**	**≥–2 and <–1 Below average**	**≥–1 and <1 Average**	**≥ 1 and <2 Above average**	**≥2 and <3 Superior**	**≥3 Very superior**
IVA-CPT									
Full	87	–3.66 (3.32)	50.6	10.3	12.6	26.4	0	0	0
Auditory	87	–3.16 (3.02)	43.7	8.0	23.0	24.1	1.1	0	0
Visual	87	–3.49 (3.60)	39.1	17.2	11.5	29.9	2.3	0	0
Trails									
A	82	–2.71 (4.56)	28.0	11.0	11.0	45.1	4.9	0	0
B	71	–2.34 (3.15)	26.8	15.5	16.9	40.8	0	0	0
PASAT									
2.4 s	51	–1.41 (0.83)	0	21.6	54.9	21.6	2.0	0	0
2.0 s	51	–1.08 (0.95)	2.0	17.6	25.5	52.9	2.0	0	0
			% with specified number of Bells missed						
			0		**1**	**2**	**3**		**>3**
Bells test (raw score)[a]									
Left	91	12.48 (4.48)	48.4		22.0	5.5	5.5		18.7
Center	91	4.42 (1.22)	71.4		16.5	4.4	2.2		5.5
Right	91	13.57 (2.62)	50.5		25.3	9.9	3.3		11.0

Note: IVA-CPT = Integrated Visual and Auditory Continuous Performance test; PASAT = Paced Auditory Serial Addition Test.
[a] Maximum raw score Bells left and right = 15; Bells center = 5.

used to accommodate multiple comparisons. The results revealed a significant main effect for ethnicity, $F(30, 21) = 2.283$, $P = .026$, $\eta^2 = .985$. There were no significant main effects for gender or hemisphere ($P > .05$). Contributing significantly to the main effect of ethnicity were performance on Trails A ($P = .010$) and the left side of the Bells test ($P = .002$). On both measures, participants of European ancestry produced significantly better scores than Māori participants.

There was also a significant interaction between ethnicity and gender, $F(10, 7) = 3.740$, $P = .047$, $\eta^2 = .842$, to which performance on the left side of the Bells test contributed ($P = .011$). Those of European or other ethnicity did not differ significantly by gender in their performance on the left side of the Bells test. However, while Māori women performed particularly well on this task, Māori men performed particularly poorly. As noted earlier, the small number of Māori in the sample (n = 11) means that these findings require replication.

Bivariate correlations were then generated between scores across measures of attention and the continuous demographic variables age and time since stroke. Also of interest were correlations between measures of attention and overall level of functional independence (Barthel Index) and a screening measure for cognitive function (MMSE). Because of the number of correlation coefficients generated, correlations significant at the .05 level should be viewed with caution due to the possibility of type I errors. **Figure 1** has been produced to assist in the interpretation of these findings. As can be seen in **Table 3**, age was only significantly correlated with Trails B with $P < .05$. Time since stroke was significantly related to all attention measures except the slowest PASAT trial (these relationships are presented graphically in **Figure 1A**, where performance on attention measures was much more variable nearer to the time of stroke and improved as time since stroke increased). Reduced functional independence (Barthel Index) was also significantly related to increased attention difficulties as

indicated by performance on each section of the Bells test, IVA-CPT full-scale and visual attention quotient, and Trails A (see **Figure 1B**). General cognitive deficit (MMSE) was also significantly related to increased attention deficit on the Bells test, IVA-CPT, and Trails A and B (see **Figure 1C**). As can be seen in **Figure 1C**, IVA-CPT scores showed improvement once MMSE scores reached 24, whereas improvement in Trails A was most evident once MMSE reached 23 and Trails B showed improvement as MMSE scores increased from the minimum level for inclusion in the study (MMSE of 21). Neither the Barthel nor the MMSE was significantly related to the PASAT ($P > .05$), and these are therefore not included in **Figure 1B** or **1C**.

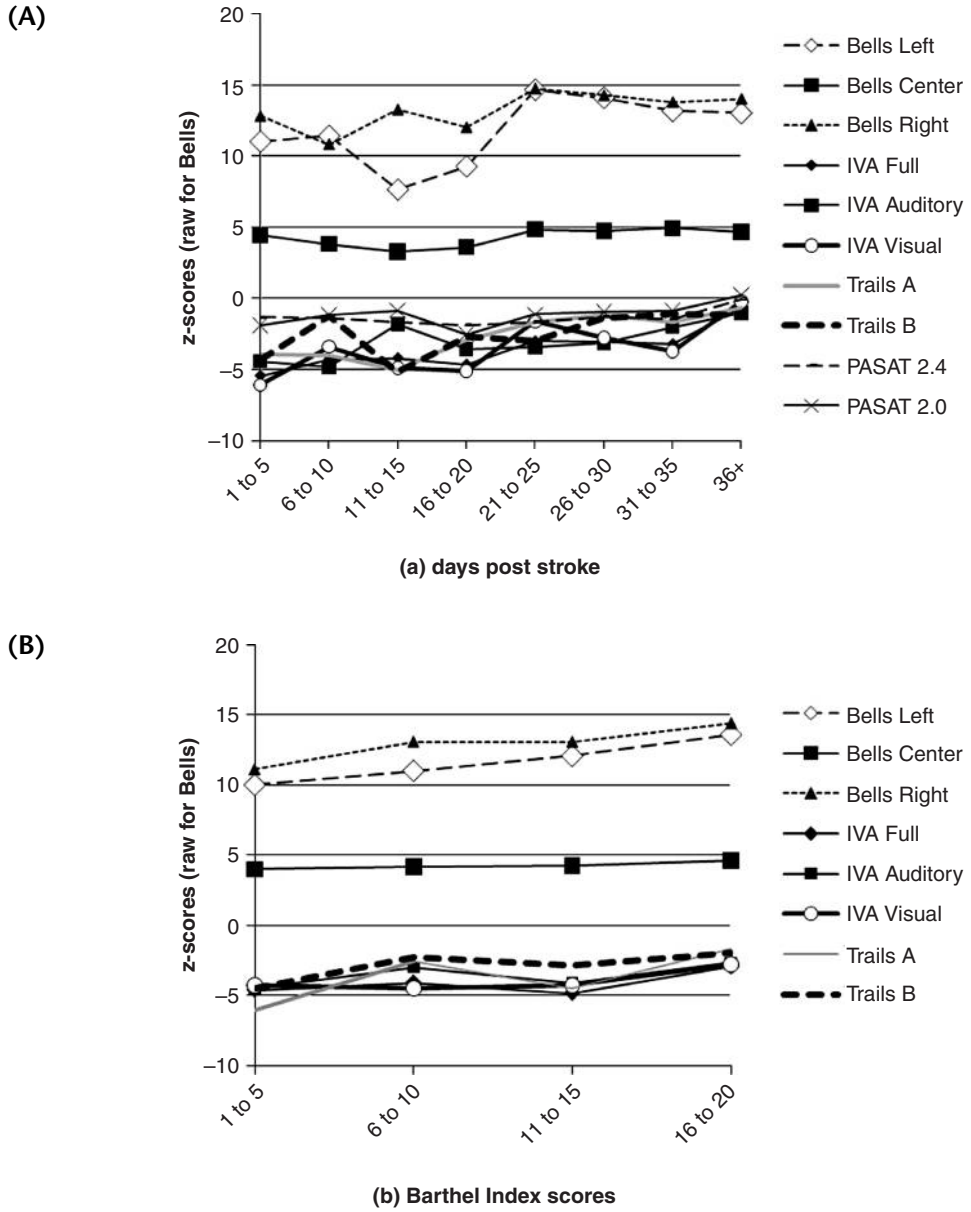

Figure 1. Mean *z* scores (raw scores for Bells test) on tests of attention in relation to (A) days since stroke, (B) Barthel Index, and (C) Mini-Mental State Examination (MMSE). IVA = Integrated Visual and Auditory test; PASAT = Paced Auditory Serial Addition Test.

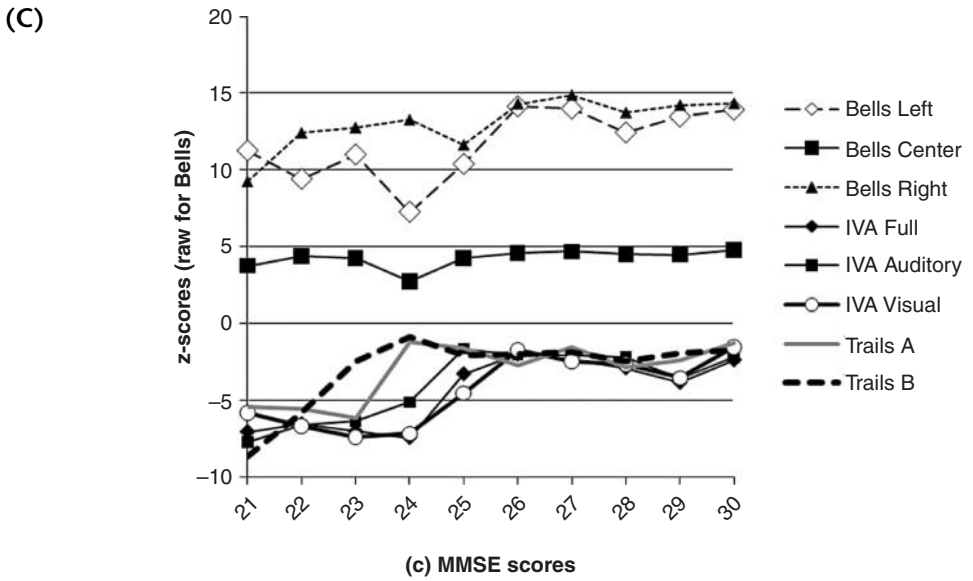

Figure 1. Continued

Correlations between attention measures and functional outcomes

Bivariate correlations were generated between scores across measures of attention and functional outcomes as measured by the CFQ, SF-36 MCS and PCS, and GHQ. Better performance on each aspect of the Bells test was significantly related to better physical component score on the SF-36 quality of life measure (r_{left} = 0.437, P = .003; r_{center} = 0.312, P = .042; and r_{right} = 0.379, P = .012). A higher SF-36 MCS score was related to better performance on Trails A (r = 0.390, P = .016) and both trials of the PASAT (r = 0.614, P = .004; and r = 0.716, P < .001, respectively). The only other correlations that reached significance were between CFQ naming and Trails B performance (r = 0.388, P = .026) and where better performance on the PASAT was related to worse CFQ memory performance (r = –0.470, P = .036).

Discussion

The literature suggests that at least 30% of individuals experience visual inattention in the acute stage post stroke.[2] In the present sample (applying criteria of ≥3 bells omitted), 24.2% of participants experienced left visual inattention, 14.3% experienced right visual inattention, and 2% had both left and right visual inattention; the result was slightly higher (36.5%) than that of Nys.[2] However, if one looks at more complex forms of attention, 30% to 60% were impaired or very impaired. This is consistent with literature

Table 3. Correlations of continuous demographic and functional variables with measures of attention

Attention measure	Age	Time since stroke (days)	Barthel Index	MMSE
Bells test				
Left	ns	.335**	.361***	.288**
Center	ns	.339**	.263**	ns
Right	ns	.290**	.414***	.372***
IVA-CPT				
Full	ns	.282*	.233*	.379***
Auditory	ns	.247*	ns	.395***
Visual	ns	.276*	.224*	.403***
PASAT				
2.4 seconds	ns	ns	ns	ns
2.0 seconds	ns	.305*	ns	ns
Trails				
A	ns	.319**	–.270*	–.293**
B	.274*	.337**	ns	–.456***

Note: MMSE = Mini-Mental State Examination; IVA-CPT = Integrated Visual and Auditory Continuous Performance test; PASAT = Paced Auditory Serial Addition Test; ns = not significant, P > .05.

*P < .05. **P < .01. ***P < .001.

that suggests that 46% to 92% of stroke survivors will present with attention deficits during acute recovery,[21] with these rates dropping to 20% to 43% at 6 weeks post stroke.[71]

Most participants in the present study produced impaired or very impaired scores in both visual and verbal modalities on the IVA-CPT but not in other measures of attention. This increased sensitivity may reflect the underpinning of the IVA-CPT task. That is, unlike other tests, the IVA-CPT was not designed to merely identify attention deficits but to evaluate the impact of treatment regimens in attention deficit hyperactivity disorder (ADHD).[72] The IVA-CPT can differentiate individuals in the control group from individuals with mild traumatic brain injury or adulthood ADHD.[73] Alternatively, differences could be due to the type of attention being assessed. Tests such as the IVA-CPT are thought to assess sustained, selective, and alternating attention. The remaining tests administered here assess focused attention/visual neglect (Bells test) and alternating and divided attention (Trails and PASAT tests).[28] Thus, differences between test performances may reflect differences in the prevalence of different forms of attention deficit, with the heightened rates for the IVA-CPT reflecting higher prevalence of sustained attention deficits; the similar findings for the Trails and PASAT tests reflect their assessment of alternating and divided attention, despite these being in different modalities.

It is also possible that test performances were affected by other abilities such as speed of processing, which was required by a number of the tests administered. For example, within the visual attention domain, Trails A and B are more reliant on fine motor speed than the IVA-CPT, and it is possible that poor fine motor ability contributed to this group performing in the very impaired range on Trails A and B. In contrast, the IVA-CPT is quite lengthy by comparison to Trails A and B, and fatigue may have contributed to the overall poorer performance on this measure, though this was not reflected in persistence scores on that task. In the auditory attention domain, the PASAT is also known to be highly reliant on speed of processing.[17] Participants who were able to complete this task performed better than those who completed the IVA-CPT; however, as previously indicated, a number of participants were too impaired to participate in the PASAT assessment. It is possible that, had these individuals participated in the PASAT, performance on this task would have been worse than the IVA-CPT, reflecting the PASAT's higher reliance on speed of processing.

An additional factor that must be considered in any examination involving self-report after stroke is anosognosia. Anosognosia is one of the most common neurobehavioral impairments after right hemisphere stroke[74,75] and can lead to significant disability.[76] As anosognosia can involve the unawareness of cognitive, emotional, and physical sequelae of stroke,[77] it can result in underreporting of difficulties on self-report questionnaires. In the present sample, 45% of participants had experienced right hemisphere stroke and were therefore at increased likelihood of experiencing anosognosia. Those with left and right hemisphere stroke did not differ significantly in terms of actual levels of cognition (MMSE cognitive screen) or disability (Barthel Index and MRS). Thus, if anosognosia had been present, we might have expected those persons with right hemisphere lesion to report fewer difficulties on self-report questionnaires. Comparison of left and right hemisphere groups (t tests) on self-reported quality of life (SF-36 MCS and PCS), day-to-day cognitive difficulties (CFQ), and overall health (GHQ-28) revealed that these did not differ ($P > .05$). Therefore, it is unlikely that anosognosia had any significant impact on self-report within this sample.

Participants who had a longer delay between stroke occurrence and assessment performed better across measures of attention. This suggests spontaneous recovery of attention deficits within the first weeks after stroke. This has implications for rehabilitation in terms of when to best assess deficits in attention and to target these for intervention. In a recent randomized controlled trial,[25] provision of 4 weeks of Attention Process Training beginning within 4 weeks poststroke resulted in significantly greater improvement than usual care, suggesting that early assessment and intervention can be of benefit.

Persons of Māori ethnicity performed worse than other ethnicities on both Trails A and the left side of the Bells test. Māori women performed

particularly well on the Bells task, whereas Māori men performed particularly poorly, though these findings are based on very small samples and must therefore be viewed with caution. It is also possible that this finding is a reflection of the small number of participants within each ethnicity by gender cell. In examining potential explanations for this difference, we note that 80% of Māori males experienced a right hemisphere stroke compared with 50% of Māori females. In contrast, males and females of European ethnicity similarly had roughly half of all strokes in the right hemisphere (50% and 53%, respectively), as did males and females of other ethnicities (40% and 50%, respectively). Left hemi-inattention resulting from right hemisphere damage may therefore have contributed to poor scores of Māori males on Bells and Trails A tests.

That there were no significant main effects for hemisphere of lesion was an unexpected finding. The literature is clear that neural systems supporting spatial attention are usually within the right hemisphere[78] and that the right posterior parietal cortex plays a central role in visuospatial and orienting attention.[79] Whereas roughly equal numbers within our sample experienced right and left hemisphere lesions, only a very small number (n = 7; 8.5%) had lesions in the posterior area of the cortex, which may have reduced our ability to replicate this relationship. However, as noted by Posner and Petersen,[80(p29)] the "left and right hemispheres both carry out the operations needed for shifts of attention in the contralateral direction, but they have more specialized functions in the level of detail to which attention is allocated."

Finally, the finding of a relationship between the physical component score of the SF-36 with visual neglect suggests that attention plays an important role in determining overall satisfaction with the level of recovery. In contrast, the mental component score on the SF-36 was significantly related to performance on both Trails A and the PASAT. Even though limitations on physical functioning that might result from visual hemineglect are obvious, the relationship of Trails A and PASAT to the mental component of quality of life is less clear. One possible factor to explain this relationship is speed of processing. That is, of the attention tests used here, the PASAT and Trails A are those most highly reflective of speed of response. Thus, it is possible that it is this aspect of the tests that is reflected in the impact of mental ability on quality of life rather than attention per se.

Strengths and limitations

The study's strengths are its use of multiple standardized assessments of various forms of attention and functional outcomes rather than reliance on a single measure, its relatively large sample of consecutively admitted patients, and the low number of patients with missing data. The main study limitation was a relatively strict inclusion criteria limiting generalizability. Although the sample size was relatively large and Bonferroni correction was used for between-group comparisons, the number of analyses performed may have led to chance findings, as might have comparison of smaller sized subgroups. Long-term changes in attention beyond the acute stage poststroke also remain to be evaluated.

Conclusions

Notwithstanding these limitations, the findings indicate that attention is a common area of deficit poststroke. Furthermore, the frequency of these deficits varies greatly across the various forms of attention that can be assessed, with greater frequency of deficits associated with more complex forms of attention. Early broad-based assessment and rehabilitation of attention should be part of poststroke rehabilitation, and rehabilitative efforts can result in significant amelioration of attention deficits.[25] Further studies are required with larger samples that include repeated assessments to determine the natural course of recovery for attention and to establish whether this differs for various forms of attention.

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