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Awareness Of Deficit And Driving Simulator Performance After Stroke.

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AWARENESS OF DEFICIT AND DRIVING SIMULATOR PERFORMANCE AFTER STROKE

by

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DEDICATION

For Andy and Ellie for their support, patience, and love.

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CHAPTER 1

INTRODUCTION

Each year, approximately 795,000 people in the United States will have a stroke (American Heart Association, 2010). Many stroke survivors who resume driving have residual physical, cognitive, and perceptual deficits that may impair the knowledge and skill necessary to drive safely, and an estimated 30 to 75% resume driving after their stroke (Mazer, Gelinas, & Benoit, 2004). Although the requisite skills for driving a motor vehicle are not completely known, it is evident that driving requires high-level cognitive, perceptual, and motor functioning. Although many stroke survivors have residual impairments in these domains (Gillen, 1998), disabilities are not, of themselves, related to increased risk of adverse driving incidents (Haskelhorn et al., 1998; Hopewell, 2002; van Zomeren et al., 1987). Compensatory skills and psychological factors such as motivation and awareness of deficit substantially influence fitness to drive (Hopewell et al., 1990; Ryan et al., 2009; Kumar, 1991; Lundqvist et al., 2000). Traditional evaluation methods such as neuropsychological and on-road testing, as well as modern technologies such as driving simulators, can substantially improve prediction of fitness to drive (Akinwuntan et al., 2002; Klavora et al., 2000; Korner-Bitensky et al., 2000; Lundberg et al., 2003; Lundqvist et al., 2000; Mazer et al., 1998; Nouri, 1987, 1993); however, evidence suggests that survivors and their significant others frequently do not make their decisions about resumption of driving based on such evidence. Research on populations with disabilities other than stroke indicates that the relation between objective indices of fitness to drive and perceptions of fitness to drive are generally much poorer than would be desired for valid decision-making (Coleman et al., 2002;

Kelly, 1999). Thus, survivors and their significant others may be making this important determination based on inaccurate information. It may be possible to evaluate survivors' and significant others' awareness and accuracy of survivor's driving ability through an objective index of driving fitness, the driving simulator.

Stroke Sequelae and Fitness to Drive

Stroke survivors may face any number of neuropsychological, cognitive, and physical impairments as the result of infarct and damage to the connecting brain structures (Coleman Bryer, Rapport, & Hanks, 2005; Gillen, 1998). Many of the impairments stroke survivors may incur involve those skills necessary for safe driving (e.g., sensory and motor functioning, visuospatial abilities, processing speed, attention, memory, and problem solving; Bryer et al., 2004; Innes et al., 2007). Stroke survivors have been shown to perform significantly worse than healthy controls (matched for age, gender, education, and driving experience) on tasks measuring a wide variety of domains, including simple reaction time, processing speed, attention, short-term and long-term memory, language, and general cognitive processing (Lundqvist, Gerdle, & Ronnberg, 2000; Sundet et al.,1995). However, research on the relative influences of impairments in these domains in discriminating between drivers and non-drivers post stroke has produced mixed results (see Akinwuntan et al., 2002; Klavora et al., 2000; Mazer et al., 1998; Nouri et al., 1987). Similarly, deficits in basic sensory-perceptual functions do not necessarily compromise driving ability (Fisk, Owsley, & Mennemeier, 2002).

Some studies indicate that survivors of right-hemisphere strokes are at greater risk for automobile accident than are survivors of left-hemisphere strokes (see Bryer, Rapport & Hanks, 2004 for review). For example, Chaudhuri (1987) found that 60% of right hemiparetic patients and 40% of left hemiparetic patients were able to drive successfully post-stroke. These findings make sense given that deficits in visuospatial ability and attention are more common following right-hemisphere stroke (Heilman et al., 2003). In contrast, several studies found no relationship between laterality of stroke and driving outcomes (Akinwuntan et al., 2002; Chaudhuri, 1987; Cushman et al., 1999; Jones, 1983; Lings et al., 1991; Mazer et al., 2003; Sundet et al., 1995). Some research indicates that deficits associated with left-hemisphere stroke (Fisk et al., 2002) such as aphasia (Golper, Rau, & Marshall, 1980; MacKenzie et al., 2003) are sufficient to compromise fitness to drive substantially. For example, Mackenzie and Paton (2003) suggest that aphasic stroke survivors should not automatically be precluded from driving but that an inability to recognize road signs and difficulty with reading comprehension might be counter-indicative to driving. One problem in evaluating the literature regarding laterality of stroke and fitness to drive is that many studies exclude persons with aphasia. Also, survivors of left-hemisphere stroke may be referred for driving evaluations less often than survivors of right-hemisphere stroke, whose typical deficits are more obviously related to driving fitness.

Visuospatial neglect (i.e., hemi-inattention), a deficit common among survivors who sustain right-hemisphere stroke, has been found to be a significant predictor of whether survivors were approved to drive post-stroke (Sundet, Goffeng, & Hofft, 1995). While in driving simulators, stroke survivors with neglect displayed less eye and head movement than did similarly aged controls with normal vision; in contrast, stroke survivors with hemianopia (visual field cut) but without neglect displayed more head movement than the normal controls (Szlyk, Brigell, & Seiple, 1993). This finding may indicate that survivors with sensory-only vision problems can adjust for their limitations; however, the sample for this study consisted of only 6 stroke survivors, only 3 of whom had neglect and simulator time was limited to 5 minutes.

Several authors have suggested that risk for accidents is moderated by *higher-order cognitive abilities* such as executive functioning (Coleman et al., 2002; Daigneault et al., 2002; Hopewell, 2002; Mazer et al., 1998; Rapport et al., 1993; Schanke et al., 2000). In addition to regulating skills essential to driving such as complex attention and multi-tasking, self-regulatory aspects of executive control affect the functional capacity of other cognitive and motor functions. For example, the functional range of peripheral vision is inversely related to cognitive load; thus, peripheral vision can be intact but hindered by the complexity of the cognitive challenge (Fisk et al., 2002). The component of executive functioning associated with self-awareness of deficit appears particularly important to driving fitness (Bogod, Mateer, & MacDonald, 2003; Burgess, Alderman, Evans, Emslie, & Wilson, 1998; Ryan et al., 2009). Yet, many stroke survivors resume driving despite increased risk associated with impairments for which they cannot compensate safely. Knowledge of accident risk alone may not be sufficient to alter behavior patterns (McKenna & Horswill, 2006). It is not clear whether these survivors inaccurately believe that they are fit to drive (Heikkilä, 1999) or drive despite knowledge that they are at high risk (Lings, 1991). The accuracy of perceptions regarding fitness to drive has a direct relationship to the validity of decisions regarding driving behavior.

Self-awareness of deficit

Clearly, a stroke survivor's awareness of residual deficits can be an important factor in whether they are fit to drive. Persons who are aware of their deficits are less likely to engage in high-risk behavior that exceeds their abilities than are persons who do not fully appreciate their deficits, and underappreciation of even mild deficits can substantially increase risk if the person chooses to drive (Rapport et al., 1993). Self-monitoring functions of executive control are essential to driving risk, because awareness of deficit moderates the recognition of need to invoke appropriate compensatory strategies (Rapport et al., 1993, 1998a, 1998b).

Unawareness of deficit is commonly observed following stroke. Traditional literature on anosognosia, the unawareness of illness or deficits, purports that it is more commonly observed following right-hemisphere insult than left-hemisphere insult (Heilman et al., 2003; Jehkonen, Laihosalo, & Kettunen, 2006; Karnath, Baier, & Nägele, 2005, Spalletta, Ripa, Bria, Caltagirone, & Robinson, 2006). Lesion mapping in 27 stroke survivors (Karnath, Baier, & Nägele, 2005) indicated that anosognosia for hemiplegia/hemiparesis was significantly associated with right posterior insula lesions as compared to individuals with hemiplegia/hemiparesis but awareness of their deficits. Jehkonen, Ahonen, Dastidar, Laippala, and Vilkka (2000) found that among patients with acute right hemisphere infarction, there was a double dissociation of anosognosia for neglect and hemiparesis, as well as anosognosia for neglect and unawareness of illness. This finding is consistent with the general literature in a variety of neurological disorders indicating that unawareness can be domain specific rather than a global phenomenon (Hart, Sherer, Whyte, Polansky, & Novack, 2004; Sherman et al., 2007).

Among stroke survivors, awareness is multidimensional and may differ across domains (see Orfei et al., 2007 for detailed review; Vallar & Ronchi, 2006; Vuilleumier, 2004).

Fischer, Trexler, and Gauggel (2004) used a mixed neurological sample of traumatic brain injury (TBI), stroke survivors, and orthopedic controls to examine possible domain differences, as well as awareness of activity limitations, using the Patient Competency Rating Scale (Prigatano & Fordyce, 1986). Participants predicted how they would perform on a test of motor ability (finger tapping) and cognition (list learning). Neither group over-predicted performance on simple motor tasks in any of the groups; however, the TBI/stroke group overestimated on the cognitive task with the TBI participants showing greater overprediction than stroke participants. When comparing staff and participant ratings in activity limitations, the control group with orthopedic injury underestimated and the TBI/stroke group overestimated their level of functioning on the total score and on the social/emotional subscale. Participant and staff estimates were in agreement on the physical/self-care subscale.

Similarly, in a study of 87 stroke survivors, comparison between self-ratings of cognitive abilities and the ratings of hospital staff members on the same measures, revealed little agreement (Gauggel, Peleska, & Bode, 2000). There were moderately high correlations between cognitive test scores and ratings made by staff, but much lower correlations between the tests and self-ratings provided by survivors. Conversely, when comparing patient and significant other reports of ability, these authors found that the largest discrepancy in ratings occurred in the evaluation of motor activities. On cognitive and emotional aspects, patients actually rated themselves as more impaired than significant others did (Gauggel, Peleska, & Bode, 2000). A possible explanation for this deviant finding is that patients' cognitive deficits were the focus of therapy or conversation with significant others due to safety concerns and therefore were more salient during questioning. Similarly, the discrepancy between patient and significant other ratings on motoric ability may be due to lack of awareness by the patient or the significant others' safety concerns and desire to monitor patient activity level. Previous work (Coleman et al., 2002; Rapport et al., 2006; Scott et al., 2009) has demonstrated that significant others frequently control patients' mobility by "holding the keys" when determining if stroke survivors can resume driving.

These studies indicate that stroke survivors may have differential awareness of their deficits and strengths across domains (Orfei et al., 2007). Theories offered to explain impaired awareness of deficit help clarify differential awareness of deficits.

General theories (Flashman & Strong, 1995; Flashman, Amador, & McAllister, 1998; Allen & Ruff, 1990) of self-awareness distinguish between psychological and neuropsychological/cognitive factors and levels of awareness. Deficits threatening to the individual may not be fully processed and therefore awareness is limited. Vuilleumier (2004) suggested that patients must complete three steps (ABC: Appreciate, Belief, Check) to have full awareness of their deficits. Defects in "ABC" functioning could differentially apply to domains of functioning, explaining dissociations in awareness. General theories of awareness also suggest that there is an executive or supervising control function directing subordinate cognitive skills. Research has found that executive functioning deficits in set-shifting and flexibility are more frequent in patients with impaired self-awareness (Starkstein, Fedoroff, Price, Leiguarda, et al., 1993). Memory impairment (Marcell et al., 2004), specifically the failure to integrate new information regarding deficits and impairments in attention (Starkstein et al., 1992) has also been postulated to explain lack of awareness. Damage to subcortical circuits, as a result of the stroke, may affect a survivor's ability to self-monitor and adjust based on novel experience (Vuilleumier, 2000).

Cognitive estimation and awareness of deficit.

Cognitive abilities required to estimate the *extent* of deficits are related to awareness of deficit. Impairments in cognitive estimation abilities in a variety of domains have been observed among persons with lesions to the frontal lobes (Shallice & Evans, 1978; Smith & Milner, 1984; Della Sala et al., 2004), as well as neurological disorders such as Alzheimer's disease (Brand et al., 2003; Della Sala et al., 2004), alcoholic Korsakoff's disease (Brand et al., 2003; Della Sala et al., 2004; Shoqeirat et al., 1988; Taylor & O'Carroll, 1995), and post-encephalic amnesia (Leng & Parkin, 1988; Shoqeirat et al., 1988). Prior research has demonstrated some relation between cognitive estimation and education (Della Sala, MacPherson, Phillips, Sacco, & Spinnler, 2003) and general intelligence (Brand et al., 2003), although studies have found the associations to general intelligence, as well as depression and state anxiety, very small in comparison to semantic memory (Freeman, Ryan, Lopez, & Mittenberg, 1995). At least one study has reported an effect of gender among healthy adults, with women performing more poorly than men; however, age was not associated with performance (Della Sala et al., 2003).

Many theories proffer that cognitive estimation is primarily related to executive functioning (e.g., Silverman, Hanks, & McKay, 2007; Shallice & Evans, 1978), although some research has not supported this association (Appollonio et al., 2003; Spencer &

Johnson-Greene, 2008; Taylor & O'Carroll, 1995). Recent theories posit an additional role of semantic memory systems as important to cognitive estimation, given the importance of both executive and semantic systems to problem-solving and "plausibility checks" (Brand et al., 2003; Della Sala et al., 2004; Freeman, Ryan, Lopez, & Mittenberg, 1995). Deficits in both of these domains are commonly observed following stroke.

The observation of deficits in cognitive estimation following stroke has a direct bearing on risk and fitness to drive: Awareness of deficit is a necessary but not sufficient condition to reduce risk, because persons who acknowledge having deficits must also accurately assess their severity in order to invoke compensatory behaviors that are proportionate to the need. Additionally, preliminary research on self-assessment of driving ability among 67 stroke survivors (Scott et al., 2009) suggests that fundamental abilities in cognitive estimation pervade self-estimates: The tendency to over- or under-estimate external stimuli on a cognitive estimation task was significantly associated with self-estimates of driving ability (rho = .48).

Therefore, stroke survivors may face the inability to accurately assess driving ability as well as any number of deficits that disrupt the actual ability to drive safely. Thus, objective measures of fitness to drive are important.

Predicting fitness to drive after stroke.

A well-accepted and standardized method of assessing whether a stroke survivor can and should resume driving has not been established. The deficits that stroke survivors typically experience are easier to elucidate than are the specific skills necessary for safe driving. However, a variety of methods have been developed to help predict driving ability. These include neuropsychological evaluations, on-road evaluations, use of driving simulators, and clinical judgments by health professionals that are made both with and without information from these resources.

On-road testing is considered a criterion standard in driving evaluations (Akinwuntan et al., 2005, Jones, Gidden, and Croft, 1983; Korner-Bitensky et al., 1998; Soderstrom, Pettersson, & Leppert, 2006) but it is expensive and may pose unnecessary safety risks. Additionally, on-road testing may not illuminate subtle psychological and motor impairments that affect fundamental driving skills (Klavora, Heslegrove, & Young, 2000). Further, hazardous situations are difficult to replicate during on-road testing, leaving therapists without evidence of how survivors might handle these scenarios.

In general, research indicates that *neuropsychological assessment* is useful in predicting fitness to drive following stroke (Akinwuntan, Feys, DeWeerdt, Pauwels, Baten, & Strypstein, 2002; Klavora, Heslegrave, & Young, 2000; Korner-Bitensky, Mazer, Sofer, Gelinas, Meyer, Morrison, 2000; Lundberg, Caneman, Samuelsson, Hakamies-Blomqvist, & Almkvist, 2003; Lundqvist, Gerdle, & Ronnberg, 2000; Mazer, Korner-Bitensky, & Sofer, 1998; Nouri et al., 1993; Nouri, Tinson, & Lincoln, 1987). In a brain injury population, the overall accuracy rate of a cognitive battery in predicting a failing score on the road was 92% and it was 71% in predicting a passing score (McKenna, Jefferies, Dobson, & Frude, 2004). Although a significant relationship between neuropsychological functioning and driving ability (as measured by on-road and off-road testing) has been found in a meta-analysis of driving studies with a dementia population (Reger, Welsh, Watson, Cholerton, Baker, & Craft, 2004), the same work suggested that neuropsychological tests should not be used as the only decision criterion, and this opinion has been supported by most experts in evaluation of driving fitness (see Bryer et al., 2005). The use of neuropsychological measures that tap multiple cognitive domains relevant to driving seem to best predict driving ability (Marshall et al., 2007). Executive functioning, processing speed, and visuospatial processing are among the domains typically tested in examining fitness to drive. Despite this recommendation, recent work has shown that a very brief neuropsychological screen (measures of visual neglect and Rey Complex Figure), in addition to on-road testing, showed good prediction of fitness to drive after stroke as defined by medical team decision (Akinwuntan et al., 2006).

Driving simulators are also available to test driving fitness (Klavora et al., 2000). The use of driving simulators and virtual reality may provide a more realistic and cost-effective driving and testing experience without the obvious safety risks of on-road testing (Schultheis & Mourant, 2001). Additionally, the use of driving simulators allows the evaluation of driving ability over a period of time (Mazer et al., 2004) and may allow for the best balance of safely assessing driving ability while attempting to test reaction to difficult situations (Bieliauskas, 2005).

Although there is little research examining the validity of driving simulators among stroke populations, the clinical utility of driving simulators has improved (Lew et al., 2005). One study to examine the efficacy of driving simulators and fitness to drive in a stroke population was conducted by Nouri and Tinson (1988). The authors compared performance on a driving simulator with on-road examinations in 38 stroke survivors.

Results of the study must be interpreted with caution because the simulator that they used considered green light acceleration and braking reaction time only; however, the simulator was helpful in predicting fitness to drive in the majority of survivors.

Research examining the relation between driving simulator performance and on-road performance has produced mixed results (Monga, 1997; Owsley, 1998; Keller, Kesserling, & Hiltbrunner, 2003; Galski et al., 1992; and Lundqvist et al., 2000). One of the most favorable studies for the driving simulator (Lundqvist et al., 2000) indicates that the driving simulator is capable of correctly classifying the overall driving skill of 85% of stroke survivors.

Despite the availability of objective indices of driving safety, they are not frequently pursued. Stroke survivors are often released from the hospital with no advice from their physicians regarding driving (Goodyear & Roseveare, 2003; Fisk, Owsley, & Mennemeier, 2002; Fisk, Owsley, & Pulley, 1997; Lundqvist, Gerdle, & Ronnberg, 2000). Fisk et al. (2002) reported that 33% of stroke survivors received advice about driving from physicians and 27% received advice from family members. Therefore, it is important to determine how individuals make the decision to resume driving.

Self-assessment of driving ability

Many stroke survivors appear to self-regulate their driving behavior (Fisk, Owsley, Pulley, 2002). Evidence of this fact may be observed in the low rate of return to driving among stroke survivors (Fisk, Owsley, Pulley, 1997; Legh-Smith et al. 1986; Fisk, Owsley and Mennemeir, 2002), as well as a reduced number of days and miles driven per week (Fisk et al., 2002; Mackenzie & Paton, 2003), an avoidance of challenging environments such as night driving, heavy traffic, and inclement weather (Fisk et al., 2002), and an increase in compensatory behaviors (Mackenzie & Paton, 2003). It is important to consider that many of these studies relied exclusively upon self-report, which requires survivors to be aware of and accurately estimate both the deficits they may possess and the verity of compensatory behaviors they actually carry out. Additionally, reductions and limitations of this nature may reflect the influences of external forces, such as the decisions of significant others or health care professionals. In fact, prior research on populations with disabilities other than stroke (e.g., TBI) suggests that significant others frequently maintain the greatest influence on whether and how much survivors drive (Coleman et al., 2002; Rapport et al., 2006).

Decision to drive after stroke

The decision regarding whether to resume driving after stroke is a complex endeavor. Support from family is essential to successful rehabilitation, including return to driving (Schanke et al., 2000). Advice from family or health care professionals can have a substantial influence on this decision-making process (Coleman et al., 2002; Fisk et al., 1997; Schanke et al., 2000).

Unfortunately, survivors and family members rarely have sufficient knowledge to form opinions on an empirical basis. For example, the relation between survivors' perceptions of their restrictions and actual medical contraindications to driving is weak (Kelly et al, 1999). Additionally, among persons with TBI, significant others appear to have the most influence regarding whether the survivor will resume driving and how much they will drive (Coleman et al., 2002; Rapport et al., 2006); however, the relation between the survivor's actual fitness to drive and the significant other's perceptions of that ability appears only modest at best (Coleman et al., 2002). This issue raises an important concern, because significant others may be limiting the stroke survivor's driving unnecessarily or encouraging resumption of driving among survivors who are unsafe to drive.

Scott et al., (2009) examined the opinions of stroke survivors and their significant others regarding domains considered important in deciding whether survivors should resume driving. Consistent with prior research on persons with TBI (Coleman et al., 2002; Rapport et al., 2006), ratings by significant others were, in general, more strongly related to survivors' actual driving status than were ratings made by the survivors themselves. Although 55% of significant others reported that professional advice was an important consideration, the extent to which they received and used this information in their decision-making process was not clear. In fact, professional advice was not among the chief domains most strongly associated with survivors' *actual* driving status (eta = .23), which included sensory (eta = .55), physical (eta = .34), and cognitive (eta = .29) functioning, as well as finances (eta = .23), emotional functioning (eta = .14) and judgment (eta = .13). Equally important, survivors did not consider professional opinion nearly as important to their decision-making process as the other domains (?): Only convenience/ease (71.6%) was rated "quite a bit" or more important a consideration by more than 50% of stroke survivors; no other domain was rated even "somewhat" or more important by more than 50% of the survivors. This previous description of test results seems a little bit difficult to follow.

Driving is an important aspect of community integration and sense of adult self.

Among individuals with disabilities, driving cessation can adversely affect social participation, occupation, and social mobility, as well as feelings of connectedness and freedom from social limitations (Anderson et al., 2002; Kiyono et al., 2001; Kreutzer et al., 2003; Siosteen, Lundqvist, Blomstrand, Sullivan, & Sullivan, 1990). Other studies have linked cessation of driving to feelings of loneliness (Johnson, 1999), anger, and frustration related to limitations on vocational and recreational activities (Hallett, Zasler, Maurer, & Cash, 1994); adverse changes in personal roles (Hallett et al., 1994); and feelings of diminished autonomy and mobility (Johnson, 1999; Lister, 1999). Alternative transportation, when available, is often not an acceptable solution because of inconvenience, unreliability, and lack of spontaneity (Brown et al., 2004, Coleman Bryer, Rapport, Hanks, 2004; Rapport, Coleman Bryer, Hanks, 2008). Additionally, the same physical or cognitive limitations that restrict driving may make public transportation difficult (Rapport, Coleman Bryer, Hanks, 2008). Given these challenges, the importance of independent transportation is clear.

Some stroke survivors resume driving despite increased risk associated with impairments for which they cannot compensate safely, whereas other survivors who could resume driving safely do not do so. Accurate self-assessment of driving skill is essential to making valid decisions regarding whether to resume driving; yet, stroke survivors are particularly susceptible to unawareness of deficit. Moreover, although survivors' significant others appear to have a great deal of influence on survivors' driving outcome, no research has established the validity of their perceptions of the survivor.

A factor inherent in judgments of the survivor made by both survivors and their significant others is the well established finding that most individuals tend to overestimate their own driving ability.

Ratings of driving ability

A large body of literature indicates that most individuals tend to overestimate the safety and skill of their own driving (Finn & Bragg, 1986; Gregersen, 1996; Groeger & Brown, 1989; Mathews & Moran, 1986; McKenna, Stanier & Lewis, 1991; Svenson, 1981). Svenson (1981) found that 88% of US drivers and 77% of Swedish drivers considered themselves safer than the average driver. Furthermore, 93% of US respondents and 69% of Swedish respondents felt they were more skillful than the average driver. Although this seminal study has been faulted for numerous design flaws (Groeger & Brown, 1989; Groeger & Grande, 1996), subsequent studies using a variety of improved designs have confirmed the fundamental finding that adults typically rate themselves as above-average drivers (see Groeger & Grande, 1996 for review). In one study, participants rated themselves as less likely to get in a traffic accident and as having more driving skill and driving judgment than their peers (Glendon, Dorn, Davies, Matthews, & Taylor, 1996). It is important to note that most studies of driving self-assessments have focused on adults (e.g., college students) much younger than the average stroke survivor. However, Marottoli and Richardson (1998) reported that the majority of their sample of adults age 77 years and older also rated themselves as above-average drivers. Scott et al. (2007) found that 47% of stroke survivors rated themselves as better-than-average or excellent drivers. In fact, 54% of survivors who were currently driving and nearly 40% of survivors who had *ceased* driving rated themselves as currently better-than-average or excellent drivers.

Interestingly, Marottoli and Richardson (1998) found no relationship between a history of adverse driving events and self-assessment of driving ability. Twenty-seven percent of their sample rated their ability as better than their peers', even when independent judges rated them as having moderate to major problems on the road or when they had a history of adverse events on the road. In fact, even feedback in the form of an on-road driving test and criticism by professional driving evaluators did not appear to alter fundamental self-ratings of driving ability (Groeger & Grande, 1996): Drivers' self-assessments of their general ability provided months prior to such an experience best predicted self-assessments of their ability after a road test. In the presence of explicit criticism during driving, self-ratings of the on-road performance itself were related to objective indices of the performance (e.g., number of errors during the task); however, self-ratings of general driving ability were unrelated to assessments of them provided by the driving instructor. Moreover, in the absence of performance feedback (i.e., criticism from the evaluator), drivers' self-ratings were unrelated even to their performance on the immediate on-road task (Groeger & Grande, 1996). This finding may provide insight into effective strategies for psychoeducation and drivers training of stroke survivors who have impaired self-awareness.

This rating of self as superior to the average driver appears to be a stable trait characteristic, rather than a state characteristic that responds and shifts in accordance with recent data about driving ability. Groeger and Grande (1996) discuss the "driving self" in the context of Markus and Nurius' (1986) theory of the self, as an enduring self-view that becomes increasingly entrenched and resistant to change over time and with experience. These authors suggest that in the absence of some extreme event (e.g., a severe accident), external feedback is ineffectual, and the driving self is unlikely to be accurate or amenable to long-term change. In general, drivers' self-ratings are far less variable than are the ratings they assign others (e.g., novice drivers or "average" drivers; Groeger & Grande, 1996). Feedback about driving performance tends to lower how an individual rates an imaginary other driver and generally affects ratings of nondescript drivers much more than self-ratings. Drivers' self-views of their ability are stable over time, and these self-assessments are very weakly related to objective indices of their skill.

Two theories have been proposed as explanations for drivers' over-confidence in their own abilities. Like its well-known predecessor, Festinger's social comparison theory (1954), Wills' *downward comparison theory* suggests that individuals seek out those worse than themselves as sources of comparison. As a result, their self-perception becomes distorted (see Wills, 1981 for review). McKenna et al. (1991) proposed a different explanation, the *self-enhancement bias*. They believed that an individual's perceptions are distorted so that they view themselves as superior to others around them. Thus, the self-enhancement bias is a positive-self bias whereas the downward comparison theory is a negative-other bias (McKenna et al. 1991). Some research seems to support Wills' (1981) downward comparison theory (Walton & Bathurst, 1998; Groeger & Grande, 1996), arguing that methodological flaws in McKenna et al.'s work, such as asking participants to rate themselves compared to the "average" driver, may have falsely supported the McKenna et al. (1991) theory of self-enhancement bias.

Prior work by Scott et al. (2009) supports the self-enhancement bias as individuals overestimate their driving ability, both when comparing themselves to the average driver and when comparing themselves to a known comparison target. However, comparison to a known target reduces positive self-bias regarding driving ability. This phenomenon of shift in self-view as a function of the compared-to criterion showed a disproportionate effect on stroke survivors, who became more accurate about their current driving abilities when comparing themselves to a companion whose driving skills were well known to them. Thus, comparison to a known target appeared to enhance awareness of deficit among stroke survivors. Scott et al. (2009) also suggested that positive self-bias is a trait that may reflect a pervasive characteristic of cognitive ability, as the tendency to overestimate driving ability was paralleled on a cognitive estimation task. The study by Scott and colleagues highlighted that stroke survivors may be doubly hindered in their assessment of their driving ability because of the normal adult self-bias and cognitive impairments that undermine their ability to estimate themselves accurately.

Summary and purpose

Resumption of driving post-stroke is important to community integration and functional independence, and it helps prevent feelings of isolation and depression. Stroke survivors are frequently left with deficits that hinder them from driving safely. Unfortunately, many stroke survivors are uninformed about the barriers they may face in safe driving. Fewer still are formally evaluated to determine whether a return to driving would be safe. Previous work (Scott et al., 2009) indicated that stroke survivors overestimate their driving ability, particularly when using an ambiguous comparison target, suggesting that the driving self is highly resistant to change, although it may be temporarily malleable.

Most healthy adults overestimate their driving ability, even in the presence of immediate feedback to the contrary. This phenomenon likely reflects the high personal valence of independent driving combined with entrenchment of self-view observed for many trait characteristics. However, even among healthy drivers, actual skills, and the accuracy of estimations of those skills, may vary considerably. Accurate estimations rely on fundamental skills in cognitive estimation, self-monitoring, and awareness of deficit: In judgments of driving ability, individuals must accurately assess the skills required by the task (cognitive estimation), compare their own abilities and performances to those demands (self-monitoring), and acknowledge discrepancies therein proportionately (awareness of deficit + cognitive estimation). Impairments in cognitive estimation, self-monitoring, and awareness of deficit are common following stroke; thus, the accuracy of the stroke survivor's self-assessment of driving skills may be hindered by both the sequelae of the stroke and by the positive self-bias observed in most adults. In combination, these phenomena may render stroke survivors particularly poor judges of their ability to drive safely.

A major gap in the knowledge base is the absence of studies comparing estimations of fitness to drive with objective indices of fitness to drive. Some research shows that older drivers—including stroke survivors— report that they compensate for acquired impairments by strategically limiting their driving exposure; however, the relation between perceived and actual deficits in driving skills has not been comprehensively examined. Similarly, a number of studies have shown that significant others frequently make the decision regarding whether the survivor will resume driving, and if so, how frequently and under what conditions they may drive; however, it also has been shown that significant others' judgments show only modest relation to objective indices of the survivor's fitness to drive, such as neuropsychological functioning or actual driving incidents. It is therefore important to examine the accuracy of evaluations of driving ability made by survivors and their significant others. Although the use of modern technologies in driving simulation with stroke populations is in its infancy, research indicates that it shows promise as a valid and objective index of driving skill that provides the opportunity to evaluate stroke survivors in a challenging but safe environment. Accordingly, the following hypotheses are proposed:

HYPOTHESES

Hypothesis 1: Among stroke survivors, unawareness of deficits will be inversely related to driving simulator performance. Furthermore, it is expected that unawareness of functional and cognitive deficits are more predictive of performance in the simulator than is unawareness of emotional problems. Unawareness of deficit will be measured via discrepancies between survivor self-report and informant report of survivors on the Awareness Questionnaire and the Stroke Impact Scale.

Hypothesis 2: Awareness of deficit moderates accuracy of self-evaluation of simulator performance. Previous research indicates that significant others often decide whether the survivor should resume driving; however, it is not clear that they are accurate judges. This study will extend those findings (Coleman et al., 2002) by using driving as the outcome criterion rather than performance on neuropsychological measures. Hypothesis 2 will examine ratings of the survivor's driving ability made by the survivor and the significant other and compare them to survivors' performance on the simulator.

Hypothesis 2a predicts that informant ratings of survivors' physical and cognitive abilities (assessed via the Stroke Impact Scale (SIS) and the Awareness Questionnaire (AQ)) will be more strongly correlated with survivor performance on the driving simulator than will survivor self-ratings.

Hypothesis 2b predicts that awareness of deficit (the discrepancy between survivors' SIS and AQ scores) moderates accuracy of survivors' self-ratings of driving performance: Among survivors deemed "aware" of their deficits, self-ratings for simulator performance will be significantly more accurate than unaware survivors' self-ratings for simulator performance.

Hypothesis 3: Individual differences in cognitive estimation ability will predict self-estimation of driving skills on the simulator. Hypothesis 3a predicts that performance on the Biber Cognitive Estimation Test will be related to self-evaluations of driving skills on the driving simulator and self-evaluations of cognitive, behavioral/affective, and motor/sensory abilities: The Biber Cognitive Estimation Test index of estimation discrepancy (Biber-Z) will be positively correlated with self-evaluations of driving skill. Thus, participants who overestimate on the Biber (positive Biber-Z score) will also rate their driving skills on the simulator as high. Additionally, individuals who over- or under-estimate on the Biber Cognitive Estimation Test will be less accurate on self-estimates of their performance in cognitive, behavioral/affective, and motor/sensory abilities (as assessed by survivor scores on the domains of the Awareness Questionnaire).

Hypothesis 3b predicts that performance on the Biber Cognitive Estimation Test will be related to *accuracy of self-evaluations* of driving skills on the driving simulator: The Biber Cognitive Estimation Test index of estimation discrepancy (Biber-Z) will be inversely correlated with discrepancies between reported and actual performance on the driving simulator. Thus, overestimation on the Biber (positive Biber-Z score) will be associated with overestimation of performance on the driving simulator (positive discrepancy Self-rated – Actual simulator score), whereas underestimation on the Biber (negative Biber Z score) will be associated with underestimation of performance on the driving simulator.

CHAPTER 2

METHOD

Participants

A total of 108 adults were included in this study: 54 stroke survivors and 54 significant others of those survivors. Stroke survivors were at least 3 months post stroke. Significant others were defined as individuals who knew the survivor prior to his or her stroke and who were considered by the stroke survivors to be "active" in their life. Inclusionary criteria for all participants included having driven within 3 months prior to the survivor's stroke, ability to understand English, over 18 years old, free from history of severe psychiatric diagnosis, and able to be tested within 3 weeks of their significant other. Participants were recruited at discharge from the stroke service at the Rehabilitation Institute of Michigan (RIM) and during follow-up care at RIM. Additional participants were recruited from the RIM Driving Education and Training Center, the Wayne State University Audiology and Speech Language Pathology Program, and from the community. Each participant was compensated $50 for their participation.

Measures

Doron AMOS (Advanced Mobile Operation System)-2 Driving Simulator. This state-of-the-art simulator is completely interactive and provides 240 degrees of visual field contained in a life-sized model of a typical automobile cockpit, with sensory feedback including sound, vibration, and moving air. The evaluation takes approximately 45 minutes and includes four sequences that simulate "real life" encounters: (a) residential and light business traffic; (b) rural traffic and roadways (including lane changes); (c) challenging situations that require forethought and quick response time (e.g., near collisions, emergency vehicles); and (d) a skills track module that includes assessment of brake reaction, front-end parking, and distance estimation. The specific driving scenarios were developed in consultation with RIM's Driving Evaluation and Training Center (DETC) Association for Driver Rehabilitation Specialists (ADED) certified evaluators and the technical consultants at Doron, who are nationally recognized as leading experts in evaluation and training of driving skills using simulator technology. The driving scenarios scores yielded a pass/fail score, and an overall total score as well as scores in the following domains: speed maintenance, lane placement, obeying traffic signals, stop distance, hazard avoidance, and usage of turn signals.

Awareness Questionnaire (AQ; Sherer, Bergloff, Boake, High, & Levin, 1998). The AQ was developed as a measure of self-awareness after traumatic brain injury. The 17-item survey is completed by stroke survivors about their own abilities while a version of the form is completed by significant others about the survivor. The measure was designed to assess perception of the survivor's functioning in three domains: cognitive, behavioral/affective, and motor sensory. The ability to perform various tasks after the stroke as compared to before the injury are rated on a 5-point scale ranging from "much worse" to "much better." Although the scale was originally designed for use among persons with traumatic brain injury, the test authors indicate that it is appropriate for use in populations with acquired brain injuries (Sherer et al., 1998), and it has been shown to be valid and reliable among populations other than TBI (Waldron-Perrine, et al., 2009).

Stroke Impact Scale (SIS) Version 3.0 (Duncan, Bode, Min Lai, & Perera, 2003). The SIS is a widely-used measure of functioning post stroke that was developed to determine the impact of stroke on quality of life within the past 1 to 4 weeks. It may be used to track changes in impairments and disabilities. The measure is comprised of 59 items tapping eight domains: strength, hand function, mobility, activities of daily living, emotion, memory, communication, and social participation. The SIS is completed by both stroke survivors and significant others, providing external criterion validity. Ratings are provided on 5-point scales specific to the domain being evaluated. The SIS scales have demonstrated excellent reliability and validity (Duncan et al., 1999; Duncan et al., 2003). For example, the Physical Scale shows excellent convergent validity with other criterion measures of stroke severity (e.g., Barthel Index, Functional Independence Measure, Fugl-Meyer, NIH Stroke Scale, SF-36 Physical Scale, and Duke Mobility Scale).

Biber Cognitive Estimation Task (BCET – Bullard et al., 2004): The BCET is believed to tap both executive functioning and semantic memory, requiring individuals to make reasonable judgments about everyday things. The 20-item test has five questions in each of four domains: quantity, distance, weight, and time. Individuals must provide numerical estimates as well as provide labels/units for their answers. Example items include “How many seeds are there in a watermelon?” and “How long would it take an adult to hand write a one page letter?” Responses are scored as correct if the estimate falls within the 5th to 95th percentile of estimates produced by the normative sample; responses outside the range of those percentiles are considered incorrect. Standard scoring of the BCET is a sum of correct items. Normative data indicate a test mean of

18.9 (*SD* = 1.1) and a range of 16 – 20; thus, the test shows a marked ceiling effect and restricted range of scores. In the present study, directional quality of responses (overestimation and underestimation) was examined by calculating a deviation (Z) score for each item and computing the average deviation score across the 20 items of the test (BCET-Z; Scott et al., 2009). Thus, a positive score indicated a tendency to overestimate the answer, whereas a negative score indicated a tendency to underestimate. Traditional scoring was used to evaluate survivors' overall performance on the measure.

Metacognitive Awareness of Context-Specific Cognitive Ability (Ergh, 2004): This measure borrows from the metacognitive literature and uses Metacognitive Discrepancy Scores. Procedures and scoring criteria for the Metacognitive Discrepancy Scores were described by Ergh (2004). The measure was used as follows: Following the standardized administration of simulator instructions, the participant was given the rating scale (see Appendix A) and asked to predict his/her performance in comparison to same-aged healthy people (prediction of performance). The simulator was then administered and following this, the participants were again asked to rate their performance using the same scale (postdiction of performance). After completing all scenarios within the driving simulator, stroke survivors rated their overall performance in the simulator with the metacognitive scale.

Demographic and other information: Information regarding age, gender, handedness, and level of education was collected for all participants. Additionally, from survivors, information regarding lesion location was obtained.

Procedure

Informed consent procedures were completed with all participants (survivors and significant others) per Institutional Review Board guidelines. Stroke survivors meeting eligibility qualifications were recruited before discharge from the inpatient unit and asked if they agreed to be contacted in the future to monitor their recovery. If agreeable, the survivors completed the consent process and demographic data, lesion location, and contact information was gathered. Significant others present at the survivor's discharge were asked to provide written consent at this time. Individuals who consented to participate were informed that they could decline participation when they were later contacted for the study. Approximately 3 months post stroke, the researcher called survivors and significant other pairs who had agreed to be contacted. Individuals still willing to participate gave verbal consent and an appointment to complete the measures will be scheduled. Participants recruited from other sites gave written consent at first contact with the researcher and appointments were made to complete the measures along with their significant other at a future date. All participants were informed that their performance on all measures, including the driving simulator, was anonymous and thus would have no impact on their driving status.

CHAPTER 3

RESULTS

Prior to analysis, the data were screened for violations of the assumptions associated with univariate and multivariate tests. Variables with non-normal distributions that may inflate alpha were transformed to improve normality and linearity. Results of this evaluation led to the overall driving simulator outcome variable to be winsorized which improved normality (Tabachnick & Fidell, 2006). Transformed variables were used in the statistical analyses and are noted where applicable.

Demographics for the study sample are presented in Table 1. Right-side strokes accounted for 33.3% of survivors, left-side strokes accounted for 51.9% of survivors, and 14.8% had strokes affecting either both hemispheres or the brain stem. The median length of time since stroke was 13 months. Approximately two-thirds of the survivors had resumed driving on the road (61.8%). Motion sickness prevented four participants from sufficient completion of the driving simulator to produce valid scores. Among stroke survivors, 90.9% were able to partake in the comprehensive driving simulator evaluation. Demographic variables (education, age, gender, handedness, laterality, time since stroke, and actual driving status) for the survivors who completed the driving simulator (n = 50) and those that did not complete the simulator (n = 4) are presented in Table 2.

The sample was categorized into two groups based on the Awareness Questionnaire (AQ) results (Sherer, 1998). Awareness of deficit was calculated as the discrepancy between survivor self-report and informant-report on the survivor on the

AQ: *AQ Discrepancy = (AQ self-report) – (AQ Significant Other report).* Twenty participants were classified as showing impaired awareness of deficit (positive AQ Difference scores), whereas 34 participants were classified as intact (n = 34; AQ Difference scores near zero or negative). Classification was based on the AQ Discrepancy Total Score; for exploratory analyses, discrepancy scores were also calculated for the three domains assessed by the AQ (cognitive, behavioral/affective, and motor/sensory). Table 3 presents descriptive statistics for the sample (total and by awareness group) on the AQ variables (self-report, significant-other report, and discrepancy scores), as well as the simulator variables. Demographics are also presented for survivors with intact (n = 34) and impaired awareness (n = 20) of their deficits (Table 4). Chi-square tests indicated that men and women (p = .61), location of stroke (p = .76), and driving status (p = .40) did not differ across level of awareness. ANOVAs indicated that awareness of deficits was not associated with significant differences on survivor age, education, or time since stroke (all *ps* > .30).

Seventy-four percent of survivors failed the driving simulator evaluation and 26% passed the evaluation. When examining the interaction of awareness of deficit and pass/fail status, a chi-square analysis (X^2 (1, N = 50) = 2.09, p = .32) indicated that level of awareness did not significantly predict whether survivors would pass or fail the simulator evaluation. Among survivors with intact awareness of deficit, 27% passed the evaluation and 73% failed the simulator evaluation. Similarly, 26% of survivors with impaired awareness of deficit passed the driving simulator evaluation and 74% of survivors with impaired awareness failed the evaluation.

Significant others (SOs), who were nominated by survivors as someone who knew them well and who had been active in the stroke survivor's recovery, included 49.1% spouses or romantic partners, 21.3% children of the survivor, 3.7% parents of the survivor, 15.7% other family members of the survivor (e.g. sibling), and 8.3% described as a friend or other. Demographics for significant others are presented in Table 5.

Hypothesis 1: Awareness of deficits and simulator performance

The hypothesis that awareness of deficit is related to simulator driving performance was tested with correlational analysis. Table 6 presents the correlations of awareness of deficit indices with the simulator outcomes. Among the total sample of stroke survivors (N = 54), overall unawareness of deficits was inversely related to simulator performance (r = -.31, p = .01). Survivors with less awareness of their deficits were worse drivers than were survivors with intact awareness of their deficits. Consistent with the hypothesis, unawareness of cognitive and motor/sensory skills showed a stronger inverse relationship to driving performance (r = -.33, p = .008 and r = -.40, p = .001 respectively) than did awareness of the emotional/behavioral domain (r = -.18, p = .10).

As shown in Table 3, mean Simulator Total score was higher for the group with intact awareness than for the group with impaired awareness; however, an independent t test indicated that the difference was not significant, $t(52)$ = 1.36, p = .09, d = .38.

Prediction of simulator performance was related to awareness of overall deficit (r = .22, p = .05); however, there was less difference across the individual domains of awareness in their relationships to predicted performance than to actual performance, with correlations to the separate domains of awareness ranging from .17 (cognitive) to .25 (behavioral/affective abilities). Postdiction of simulator performance showed a pattern similar to prediction: It was related to overall awareness of deficit (r = .22, p = .06), with correlations in the individual domains of awareness ranging from .14 (motor/sensory) to .28 (behavioral/affective). Among the total sample, actual simulator performance was related to simulator prediction (r = .21, p = .07) and simulator postdiction (r = .33, p = .01). Simulator prediction and postdiction were modestly correlated (r = .45, p = .001) with one another.

Lastly, of interest are the modest to strong correlations between indices of survivors' awareness of deficit and indices of accuracy in self-estimated performance on the driving simulator evaluation (*r*s .31 to .53). Accuracy of prediction was represented as the difference between predicted simulator performance and actual simulator performance (Prediction Accuracy = Predicted – Actual performance); therefore, positive T scores reflect overestimation of actual performance. For accuracy of prediction, about 15% of survivors underestimated their performance, another 25% were within 10 T points of their actual performance, 30% overestimated their performance by 10 - 20 T points, and 30% overestimated by > 20 T points. For survivors' postdiction accuracy, about 20% underestimated their performance and 24% were within 10 T points of their actual performance, whereas 39% overestimated by 10 - 20 T points and 18% of survivors overestimated by >20 T points. As shown in Table 6, the overall awareness of deficit index (AQ Difference Total) showed modest to strong relation to both prediction accuracy and postdiction accuracy, with awareness of motor/sensory deficits the most strongly correlated of the AQ domains with prediction accuracy (*r* = .49) and postdiction accuracy (*r* = .53). Consistent with the hypothesis, r to z analyses comparing the magnitude of correlations between awareness of motor/sensory deficits and prediction accuracy and awareness of behavioral/affective deficits and prediction accuracy indicated that awareness of motor/sensory deficits was significantly more strongly related to prediction accuracy than was awareness of behavioral/affective deficits ($t(51) = 1.80$, $p = .04$). Similarly, there was a strong similar trend for postdiction accuracy and awareness of motor/sensory deficits and postdiction accuracy and awareness of behavioral/affective deficits ($t(51) = 1.65$, $p = .05$). R to z analyses comparing the magnitude of prediction accuracy and awareness of cognitive deficits versus prediction accuracy and awareness of behavioral/affective deficits ($t(51) = 1.20$, $p = 0.12$) and the magnitude of prediction accuracy and awareness of cognitive deficits versus prediction accuracy and awareness of motor/sensory deficits ($t(51) = -1.05$, $p = 0.15$) were not significant. Additional r to z analyses that did not reach levels of significance included correlations between postdiction accuracy and awareness of behavioral/affective deficits and postdiction accuracy and awareness of cognitive deficits ($t(51)= -1.37$, $p = 0.09$) and postdiction accuracy and awareness of motor/sensory deficits and postdiction accuracy and awareness of cognitive deficits ($t(51) = 0.68$, $p = 0.75$). Thus, as awareness of deficit becomes increasingly impaired (high scores indicated impaired awareness), self-estimated performance is increasingly overpredicted (high accuracy scores indicate overestimation of actual performance).

Driving Simulator Performance: Logistic Regression

A logistic regression examined the prediction of driving simulator performance (pass, fail), whereas multiple regression analysis examined the prediction of driving simulator performance (total score on driving simulator). Predictor variables for these regression analyses included survivor's age, stroke severity (SIS – Physical Scale), and awareness of deficit in cognitive, behavioral affective, and motor domains (AQ difference).

A test of the full model with the five predictors against the constant-only model was significant, X^2 (5, *N* = 48) = 14.31, Nagelkerke R^2 = .37, *p* = .01, indicating that the set of predictors reliably distinguished between survivors who passed and failed the driving simulator evaluation. The model correctly classified 85.4% of cases, with 97.1% of failing survivors and 53.8% of passing survivors correctly classified. Using the Wald criterion, age (*p* = .06, odds ratio 0.92), stroke severity (*p* = .04, odds ratio = 1.06), and awareness of behavioral/affective abilities (*p* = .03, odds ratio = 9.73) made significant contributions to predicting whether a survivor passed or failed the driving simulator.

<u>Driving Simulator Performance: Hierarchical Multiple Regression Analyses</u>

Hierarchical multiple regression analysis was performed to examine the prediction of total score on the driving simulator by survivor's age, stroke severity, and awareness of cognitive, behavioral/affective, and motor deficits. The results of the multiple regression analysis are presented in Table 7. After step 1, age and stroke severity, R^2 = .10, *F*(2, 47) = 2.54, *p* = .09. When the remaining predictors were entered into the equation after step 2 (awareness of cognitive, behavioral/affective, and motoric abilities), they reliably improved the prediction of simulator performance by 24%. The overall model predicted 34% of the variance in simulator performance and was significant, $F(5, 47) = 4.41$, $p = .003$. Examination of the squared correlations indicate that awareness of motor or physical deficits ($sr_i^2 = .12$) contributed the most unique variance to the prediction of driving simulator performance, followed by awareness of behavioral/affective deficits ($sr_i^2 = .10$), age ($sr_i^2 = .07$), stroke severity ($sr_i^2 = .04$), and awareness of cognitive deficits ($sr_i^2 = .02$).

Hypothesis 2: Awareness of deficit moderates accuracy of self-evaluation of simulator performance

<u>Awareness status and Self-Estimations of Driving Simulator Performance</u>

The moderation effect was tested first via split-plot correlation analyses of predicted and postdicted estimations to actual simulator performance. Table 8 presents correlations between driving simulator indices for stroke survivors with intact ($n = 34$) and impaired ($n = 20$) awareness of deficit. Simulator prediction and postdiction were significantly related to one another among survivors with intact ($r = .42$) and impaired ($r = .41$) awareness of deficits. Among survivors with intact awareness of their deficits, simulator prediction ($r = .32$) and postdiction ($r = .25$) showed moderate relationships to actual simulator performance (i.e., self-estimates of performance corresponded to actual performance). Of note, unlike their counterparts with intact awareness of deficits, predicted simulator performance was not significantly related to actual simulator performance among survivors with impaired awareness; however, actual simulator performance was strongly related to postdiction ratings ($r = .53$). Therefore, among the impaired awareness group, self-estimates of performance did not correspond to actual performance before the simulator experience (prediction) but strongly corresponded to actual performance after the simulator experience (postdiction). Overall, awareness of deficit moderated self-evaluation of performance before and after the experience of driving the simulator.

Informant versus Survivor Ratings of Survivors' Abilities and Driving Simulator Performance

Descriptive statistics for indices of survivors' cognitive, behavioral/affective, and motor /sensory abilities as rated by the survivor (self-report) and by the informants indicated that both stroke survivors and significant others rated survivors' current cognitive (1.8 and 1.4 respectively), motor/sensory (1.62 and 1.26), and behavioral/affective (1.85 and 1.56) abilities as a “little worse” to “about the same” as they were prior to their stroke, where 0 = “much worse” and 5 = “much better” (Table 3).

Accuracy of estimated performance by self- and informant-rated abilities

Further examination of survivors' relative capacities to evaluate their abilities was conducted on the accuracy of predicted and postdicted scores. Table 8 shows a fairly consistent pattern of positive correlations between survivor self-ratings and the accuracy of their estimated simulator performance, as compared to inverse correlations between SO-ratings of the survivors and the accuracy of survivors' estimations of their simulator performance. As shown in Table 8, accuracy of prediction (i.e., Prediction Accuracy = Predicted – Actual performance) was related to self-ratings overall (r = .33); in the individual domains it related to cognitive ability (r = .30, p = .01) and motor sensory ability (r = .40, p = .002) but showed weaker relation to self-ratings of behavioral/affective ability (r = .22, p = .06). The same pattern of findings was apparent with accuracy of postdiction (i.e., Postdiction Accuracy = Postdicted – Actual performance), which was related to self-ratings overall (r = .34) and in individual domains more strongly to cognitive ability (r = .33, p = .01) and motor sensory ability (r = .43, p = .001) with weaker relation to self-ratings of behavioral/affective abilities (r = .21, p = .07). Therefore, increases in self-ratings of cognitive and motor/sensory abilities were associated with overestimations of actual simulator performance prior to the task (prediction accuracy) and after completing the task (postdiction accuracy). In contrast, accuracy of predicted and postdicted performance showed trends toward *inverse* relation to SO reports of the survivors' abilities. Accuracy of survivor's prediction ratings showed inverse relation to SO's ratings overall (r = -.23, p = .05); within the specific domains, to the survivors' cognitive abilities (r = -.22, p = .06), behavioral/affective abilities (r = -.18, p = .09) and motor/sensory abilities (r = -.20, p = .08). Accuracy of postdiction ratings showed a similar and somewhat stronger pattern: significant inverse relation to SOs' ratings of the survivors' overall abilities (r = -.30, p = .02), with correlations for specific domains cognitive (r = -.28, p = .02), behavioral/affective (r = -.27, p = .03) and a similar trend for motor/sensory abilities (r = -.21, p = .07). Survivors objectively rated as having recovered the most from their strokes made more accurate predictions and postdictions of their simulator performance than did survivors with significant cognitive, behavioral/affective, and motor/sensory deficits.

Fisher's r-to-z analyses were conducted to compare whether the differences in correlations between survivors' and significant others' ratings of abilities and accuracy of prediction and postdiction were significant. The difference in the magnitudes of correlations between prediction accuracy and survivors' ratings of overall abilities and significant others' ratings of overall abilities was significant (z = -2.91, p = .00). Also significantly different were the correlations between prediction accuracy and the awareness subscales: survivor ratings of cognitive abilities and SO ratings of survivors' cognitive abilities (z = 2.69, p = .00); survivor ratings of behavioral/affective abilities and SO ratings of behavioral/affective abilities (z = 2.04, p = .02); and survivor ratings of motor/sensory abilities and SO ratings of survivors' motor sensory abilities (z = 3.16, p < .01). The magnitude of correlations between postdiction accuracy and survivors ratings of overall abilities and SO's ratings of overall abilities was significant (z = 3.52, p < .01). Again, the magnitude of correlations between survivors' postdiction accuracy and survivors and significant others ratings of survivors' abilities on awareness domains were compared and found significant: Postdiction accuracy and survivor ratings of cognitive abilities and SO ratings of survivors' cognitive abilities (z = 3.18, p < .01); survivor ratings of behavioral/affective abilities and SO ratings of behavioral/affective abilities (z = 2.47, p = .01); and survivor ratings of motor/sensory abilities and SO ratings of survivors' motor sensory abilities (z = 3.40, p < .01).

In the total sample, as SO ratings of survivors decreased (i.e., rated as more impaired), survivors' estimation accuracy was worse. In contrast, as survivors' self-ratings increased, self-estimation accuracy worsened (more discrepant from actual). The correlations for the two awareness groups between simulator indices and both self-ratings and SO-ratings of survivors' abilities also are shown in Table 8. In general, they show a pattern similar to that observed in the total sample, but the magnitudes are much weaker by comparison, likely due to restriction of range.

Independent t test indicated that there was a significant difference in prediction of simulator performance between the awareness groups, $t(51) = -1.90$, $p = .03$, $d = .53$. The means for the prediction of performance were in the direction indicating that survivors who are more aware of their deficits made a lower estimate of their driving skill (M = 50.21, SD = 6.68) than did those who had impaired awareness of their deficits (M = 54.18, SD = 8.41). There was also a significant difference between awareness groups on postdiction of simulator performance, $t(49) = -1.81$, $p = .04$, $d = .51$. Similarly, the means for the postdiction of performance were in the direction indicating that survivors who had intact awareness of deficits made a lower evaluation of their driving skill (M = 46.73, SD = 5.39) than did those who had impaired awareness of their deficits (M = 50.05, SD = 7.71). Additionally, an independent t test (with Levene's correction for heterogeneity of variance) indicated that awareness groups differed significantly in their accuracy of prediction, $t(28.55) = -2.22$, $p = .02$, $d = .68$ whereas another independent t test found awareness groups differed significantly in their accuracy of postdiction $t(49) = -3.22$, $p = .001$, $d = .91$. The means for the accuracy of prediction and postdiction were in the direction indicating that survivors who had intact awareness of deficits made more accurate estimates of their driving skill (M = 11.72, SD = 11.03 and M = 7.45, SD = 10.21, respectively) than did those who had impaired awareness of their deficits (M = 21.26, SD = 17.25 and M = 18.36, SD = 13.92, respectively).

Next, to examine survivors' relative capacities to evaluate their abilities, correlational analyses were conducted to determine whether informant ratings of survivors' physical and cognitive abilities were more strongly correlated with survivor performance on the driving simulator than were survivor self-ratings of the same abilities. Table 8 presents correlations of self-ratings and SO-ratings of survivors with the simulator evaluation indices for the total sample and the two awareness of deficit groups. Among the total sample, survivor self-ratings of behavioral/affective abilities (r = -.07) were unrelated to driving simulator performance (as measured by the simulator total score) whereas self-ratings of physical (r = -.29) and cognitive (r = -.24) abilities showed significant inverse correlations with driving ability (Table 8). Point-biserial correlations indicated that survivors' ratings of their behavioral/affective (r_{pb} = .08, p = .30) and motor sensory (r_{pb} = -.10, p = .24) abilities were not significantly related to their pass/fail status on the simulator; however, self-ratings of cognitive abilities were related (r_{pb} = -.20, p = .08) to pass/fail status. Contrary to the proposed hypothesis, significant others' reports of stroke survivors' cognitive (r = .17) and behavioral/affective (r = -.16) abilities were not significantly related to the survivors' driving performance in the simulator as measured by the simulator total score (Table 8); the significant others' reports of survivors' motor/sensory abilities (r = .21, p = .06) were weakly related to the simulator total score (Table 8). The significant others' ratings of stroke survivors' abilities were not significantly related to the pass/fail status of stroke survivors on the driving simulator (r_{pb} .02 to .09).

As shown in Table 8, correlations for the separate groups of survivors with intact and impaired awareness of their deficits were generally small and nonsignificant, possibly reflecting restriction of range. Neither self-ratings nor SO ratings of survivors' abilities were well related to actual simulator performance, predicted simulator performance, or postdicted simulator performance for either group, with a few notable exceptions. Among the group with intact awareness of deficits, SO-ratings of motor/sensory abilities were significantly correlated with actual simulator performance (r

= .32), as well as predicted (*r* = .42) and postdicted (*r* = .37) performance. Survivor ratings of the motor/sensory domain were also significantly correlated with predicted performance (*r* = .34) among the intact awareness group.

Overall, the survivors' and informants' ratings of the survivors abilities showed weaker relation to actual simulator performance than did the awareness of deficit indexes that were generated from the differences between their ratings.

In sum, Hypothesis 2 was largely confirmed: Awareness of deficit moderated the accuracy of self-evaluation of simulator performance. Among survivors with intact awareness of their deficits, prediction and postdiction self-ratings of performance were related to actual driving performance. Among survivors with impaired awareness of their deficits, only postdiction correlated with actual driving performance. In contrast to the hypothesis, significant others' reports of survivors' abilities were not as strongly related to actual driving performance as were survivors' self reports of those same abilities. Additionally, the objective and self-ratings of the survivors' abilities showed weaker relation to actual simulator performance than did the awareness of deficit indexes that were generated from the differences between their ratings. Further, as objective ratings of survivors' abilities decreased, the accuracy of survivors' estimation was worse. In comparison, as survivors ratings of themselves increased, their accuracy of estimation was worse.

Hypothesis 3: Cognitive estimation ability predicts self-estimation of driving skills

Table 9 presents descriptive statistics for the sample (total and by awareness group) on the BCET variables (traditional and Z scoring). Independent t tests indicated that survivors with intact and impaired awareness of deficits differed on their estimation of quantity with traditional BCET scoring ($t(50) = 2.60$, $p < .01$, $d = .75$). Independent t tests indicated that awareness of deficits was not otherwise associated with significant differences on cognitive estimation tests (all *ps* > .12).

Cognitive Estimation and Self-Estimation

To determine whether general skills in cognitive estimation were related to self-evaluations of driving skills on the simulator, correlational analyses were conducted between the BCET and driving simulator indices (Table 10). Differences in findings were apparent when different methods of scoring the BCET were instituted. When using BCET Z scores and examining the total sample of stroke participants, simulator prediction was correlated with general cognitive estimation skill ($r = .46$, $p = .00$). Actual simulator performance ($r = .10$, $p = .25$) and simulator postdiction ($r = .08$, $p = .29$) were unrelated to cognitive estimation among the total sample. Among survivors with intact awareness, general cognitive estimation skill was related to simulator prediction ($r = .41$, $p = .008$) but not to simulator postdiction ($r = .02$, $p = .46$) or actual simulator performance ($r = .06$, $p = .36$). A strong positive relationship was also found between simulator prediction and general cognitive estimation skill among the group with impaired awareness ($r = .56$, $p = .01$). A Fisher's r to z analysis indicated that the magnitude of the correlations between intact and impaired survivors and prediction of driving ability and general cognitive estimation skill was not significant ($z = -0.65$, $p = .74$). Similar to survivors with intact awareness, simulator postdiction ($r = .21$, $p = .22$) and actual simulator performance ($r = .10$, $p = .35$) were not substantially related to cognitive estimation among stroke survivors with impaired awareness. When using traditional scoring methods for the BCET and examining the total survivor sample, general cognitive estimation was related to actual driving performance (r = .23, p = .05) but not related to prediction (r = .05, p = .36) or postdiction (r = .16, p = .14) of driving ability. Among survivors with intact awareness, general cognitive estimation was not related to actual driving performance (r = .26, p = .07) or predicted (r = -.01, p = .49) or postdicted (r = .27, p = .06) ability to drive although there was a small trend toward significance for actual and postdicted performance. There were no significant correlations between general cognitive estimation and actual driving ability (r = .16, p = .27) and prediction (r = .19, p = .23) or postdiction (r = .11, p = .34) of ability for survivors with impaired awareness of deficits.

Correlational analyses were also conducted comparing cognitive estimation and self-evaluations of cognitive, behavioral, or motor/sensory abilities (Table 11). In the total sample, cognitive estimation (as determined with the Z scores) and self-ratings of cognitive abilities (r = .05, p = .34) and motor/sensory abilities (r = .09, p = .26) were not related. Cognitive estimation was also not meaningfully related to the survivors' behavioral/affective abilities (r = .18, p = .10). For survivors with intact awareness, cognitive estimation and survivor self-estimates of cognitive abilities (r = .34, p = .02 and motor/sensory abilities (r = .37, p = .02) were significantly related, with a similar trend observed for behavioral/affective abilities (r = .28, p = .06). Among survivors with impaired awareness, cognitive estimation and survivor self-estimates of cognitive abilities (r = -.06, p = .41), behavioral/affective abilities (r = .22, p = .19), and motor/sensory abilities (r = -.03, p = .46) were not significantly related. When using traditional scoring of the BCET, correlations between survivor rated abilities and general cognitive estimation mostly ranged from moderate to strong. Among all survivors, cognitive estimation was significantly related to self-rated cognitive ($r = -.46$, $p = .00$), behavioral/affective ($r = -.35$, $p = .01$), and motor/sensory ($r = -.45$, $p = .00$) abilities. For survivors with intact awareness of deficits, cognitive estimation was significantly related to self-rated cognitive abilities ($r = -.41$, $p = .01$) but not to survivor opinions of behavioral/affective ($r = -.19$, $p = .14$) or motor/sensory abilities ($r = -.19$, $p = .14$). The relationship between cognitive estimation and self-rated cognitive ($r = -.51$, $p = .02$), behavioral/affective ($r = -.46$, $p = .03$), and motor/sensory ($r = -.66$, $p < .01$) abilities was strong amongst survivors with impaired awareness of deficits.

Cognitive Estimation and Accuracy of Self-Estimates of Driving Skill

Accuracy of prediction (z scoring: $r = .12$, $p = .19$; traditional scoring: $r = -.20$, $p = .09$) and postdiction (z scoring: $r = -.09$, $p = .28$; traditional scoring: $r = -.19$, $p = .10$) was unrelated to general cognitive estimation skill among survivors. Among survivors with intact awareness, prediction (z scoring: $r = .19$, $p = .15$; traditional scoring: $r = -.27$, $p = .07$) and postdiction (z scoring: $r = -.08$, $p = .34$; traditional scoring: $r = -.25$, $p = .09$) were not significantly related to cognitive estimation (Table 10). Similarly, among survivors with impaired awareness, cognitive estimation was not significantly related to prediction (z scoring: $r = .12$, $p = .32$; traditional scoring: $r = -.06$, $p = .41$) and postdiction (z scoring: $r = -.05$, $p = .43$; traditional scoring: $r = .00$, $p = .50$).

CHAPTER 4

DISCUSSION

Impaired awareness of deficits among stroke survivors predicted poor driving performance in the simulator. The findings indicated that awareness of cognitive deficits and motor/sensory deficits were more strongly associated with driving performance than was awareness of behavioral and affective problems. These findings were paralleled in general cognitive estimation skills: Persons who tended to overestimate external things like quantity, distance and time also overestimated (overpredicted) their driving skills. Additionally, awareness of deficit moderated survivors' accuracy of self-evaluation of driving skill: Survivors with intact awareness of their deficits showed ability to predict their actual driving performance prior to driving in the simulator and evaluate their performance accurately after driving the simulator. In contrast, survivors with impaired awareness of deficits showed poor prediction of their actual performance in the driving simulator; however, the accuracy of their self-evaluations improved substantially after completing the driving simulator task (postdiction).

Survivors with intact or impaired awareness of deficit did not differ in age, education, or time since stroke and their cognitive, behavioral/affective, and motor/sensory abilities were evaluated as a little worse to about the same as they were prior to their strokes. Age, stroke severity, and awareness of deficits provided unique information about fitness to drive. When considering overall driving skills, as predicted, awareness of motor/sensory deficits contributed the most substantial value to the prediction of driving ability, followed by awareness of behavioral/affective deficits, age, stroke severity, and awareness of cognitive deficits. In determining whether survivors passed a driving evaluation, age, stroke severity, and awareness of behavioral/affective deficits uniquely contributed to driving performance. These findings suggest that evaluating survivors' awareness of deficit is an important factor in determining fitness to drive.

Awareness of Deficit and Driving Performance

Survivors with impaired awareness of their deficits were worse drivers than were survivors with intact awareness of their deficits. Specifically, impaired awareness of cognitive and especially motor/sensory deficits predicted poor driving, and they were substantially stronger predictors than was awareness of emotional and behavioral deficits. These findings support previous research showing that awareness of disability moderates driving outcomes (Ryan et al., 2009). It also expands the literature by replicating Ryan et al.'s (2009) finding in a different neurologically impaired population and with a different outcome measure of driving (driving simulator versus driving records).

The source of ability estimates and how these opinions predicted driving simulator performance was important. Survivors' estimates of physical and cognitive abilities were more strongly related to survivor performance on the driving simulator than were informant estimates of the same abilities. Contrary to prediction, there was not a strong link between significant others' opinions of stroke survivors' cognitive, motor/sensory, and behavioral/affective abilities and the survivors' driving. Previous research (Coleman et al., 2002; Scott et al., 2009) has shown that significant others often decide whether stroke survivors resume driving but often do so without considering objective indices of fitness to drive. The present findings may suggest that even if presented with objective evidence of survivors' abilities, significant others consider other factors and do not make decisions about survivors' resumption of driving based on objective evidence. Another explanation for the findings is that although significant others are accurately estimating survivors' cognitive, behavioral/affective, and motor/sensory deficits, the survivors' awareness of those deficits is actually more pertinent to driving ability. Indeed, these findings indicate that survivors' awareness of their deficits was a stronger indicator of driving performance than were survivor or significant other estimates of survivors' abilities alone.

In support of the theory that awareness is multidimensional and may vary across domains (see Orfei et al., 2007 for a review), differential awareness of cognitive, motor/sensory, and behavioral/affective deficits was suggested by the differential relationships between these domains and simulator performance in this study. Poor awareness of cognitive and motor/sensory deficits was strongly predictive of poor performance in the driving simulator whereas awareness of behavioral/affective deficits was unrelated to simulator performance. Individuals with impaired awareness of their behavioral/affective deficits overestimated their driving skills prior to and after a driving evaluation whereas individuals with impaired awareness of their motor/sensory deficits overpredicted their driving skills prior to the evaluation. Impaired awareness of cognitive deficits was not associated with prediction or postdiction of driving skill. It may be also be that poor awareness of cognitive and motor/sensory skills, and therefore the lack of feedback about these skills, is particularly detrimental to a survivor's ability to predict and adjust ratings of their driving ability. Stroke survivors' ability to accurately predict driving skills prior to resuming driving after stroke and then make accurate estimations of driving performance is clearly important in ensuring both the safety of the survivor and other drivers on the road. If survivors predict they will not be able to resume driving safely, or if they return to driving and recognize that their driving skills are insufficient, they can seek out drivers' rehabilitation training or alternative methods of transportation.

Awareness of deficit moderates accuracy of self-evaluation of simulator performance

Among survivors aware of their deficits, prediction and postdiction of driving skill were modestly related to actual simulator performance; among survivors unaware of their deficits, only postdiction estimates were related to actual driving skill. One possible explanation for this pattern of self-evaluation is that although survivors in general may overestimate their driving ability (Scott et al., 2009) survivors with impaired awareness of deficits overestimate their level of driving skill and *underappreciate* their deficits. Therefore, survivors with impaired awareness of their deficits were less likely to accurately predict their driving skills; however, after driving, their self-evaluations were strongly associated with their actual performance and the *accuracy* of their self-evaluations improved substantially. Thus, survivors with impaired awareness of their deficits benefitted substantially from the experience in terms of improved accuracy of self-evaluation and they benefitted more than did the participants with intact awareness. Groeger and Grande's work (1996) suggests that feedback provided about driving skill may be beneficial in improving the accuracy of an individual's estimate of a specific driving behavior; however, overall opinion of driving ability is not influenced by instructor feedback on an actual driving task.

Although the present study indicates that stroke survivors may have sufficient cognitive flexibility to adjust their awareness of deficits, and therefore may be able to adjust their driving accordingly, it is unclear how long the improved insight into driving skill may last. It is unclear whether survivors would alter their opinions of themselves as a driver overall or would change the accuracy of their predictions of driving skills at some point in the future. Despite this unanswered question, the potential positive influence of using the driving simulator as an intervention to improve both driving skills and accuracy of self-evaluation of those skills warrants further investigation.

Additionally, as survivors' opinions of their general abilities improved, they became less accurate in their self-estimates of driving skill. This relationship was observed for self-estimates of cognitive and motor/sensory abilities but not for behavioral/affective abilities and it suggests a tendency for overestimation across domains among stroke survivors. In contrast, survivors' perspectives of their cognitive, behavioral/affective, and motor/sensory abilities were not related to whether survivors passed the driving evaluation. Interestingly, significant others' perspectives on survivors' behavioral/affective abilities were related to whether they passed the driving evaluation. As survivors' ability to manage their behavior and affective experiences declined, as per significant others' report, survivors became more likely to fail the driving evaluation. It is likely that methodological issues account for the limited predictive value of pass/fail status on the driving simulator. Due to its dichotomous nature, pass/fail outcome was less sensitive than the continuous simulator outcome in evaluating driving skill.

Additionally, the pass/fail outcome included survivors recommended to drive with restrictions or after remediation of skill and survivors who may have driven well throughout the evaluation except for one significant error, such as causing a major accident. These factors reflect the non-linear nature of the pass-fail designation.

In Scott et al. (2009), overestimation of driving ability (as compared to an "average driver") was mirrored on a performance task. This research extends that work by demonstrating that overestimation of driving ability (accuracy of actual driving performance) was mirrored in overestimation of ability to perform life skills. Furthermore, as significant others' evaluations of survivors' abilities improved, so did the accuracy of survivors estimates of their own driving skill. This supports the use of significant others as accurate informants on survivors' abilities.

Cognitive Estimation and Self-Estimation of Driving Ability

Cognitive estimation has been described as a process of using readily-available common knowledge in a novel manner to answer a question for which an exact answer is not known (Shallice & Evans, 1978). Although much of the prior research on cognitive estimation has focused on its relationship to other cognitive skills (Axelrod & Millis, 1994; Brand et al., 2003; Bullard et al., 2004), Scott et al. (2009) found that overestimation on general cognitive estimation tasks was related to overestimation of driving skills. This work adds to the current literature by extending these findings: Survivors general tendency to over- and underestimate cognitive skills was associated with prediction of performance on the simulator in both survivors with intact and impaired awareness of their deficits. This relationship was stronger amongst survivors with impaired awareness of their deficits. Additionally, cognitive estimation was modestly related to awareness of cognitive and motor/sensory abilities among survivors with intact awareness of deficit such that the more accurate survivors were in their cognitive estimation, the more favorably they evaluated their abilities. However, cognitive estimation scores were minimally related to actual driving performance and not related to postdiction or the accuracy of self-evaluations of driving skills on the simulator. The present findings support the idea that an underlying mechanism of estimation pervades cognition and sense of self (Scott et al., 2009). However, it appears that feedback on performance (through actual driving experience) or having additional data to use in making estimates may alter survivors' awareness of their abilities. This may provide a unique opportunity to raise stroke survivors' awareness of driving ability and improve driving safety.

Conclusions and implications

In conclusion, the present study demonstrated that knowledge of survivors' awareness of deficit provides substantial information in understanding survivors' driving ability. Awareness of deficit was related to actual driving skill. More specifically, awareness of cognitive and motor/sensory deficits was related to actual driving skill whereas awareness of behavioral/affective deficits was related to prediction and postdiction of driving skill. Awareness of deficit was also strongly associated with the accuracy of prediction and post-evaluation estimates made by stroke survivors. Survivors with intact awareness of deficit demonstrated better driving skills and were more accurate in their prediction of these driving skills as compared to survivors with impaired awareness of their deficits. Survivors with impaired awareness of deficit demonstrated substantially improved accuracy in their postdiction as compared to survivors with intact awareness of deficit. Thus, the opportunity to drive in a simulator appeared beneficial to survivors in that when provided with feedback, survivors became better at evaluating their level of driving skill. Potentially, survivors could use this information to alter their driving habits. Awareness of deficit was also associated with cognitive estimation. Among survivors with intact awareness of deficit, survivors' opinions of their abilities were associated with cognitive estimation skill, however; among survivors who were unaware of their deficits, estimates of abilities and cognitive estimation were unrelated. Cognitive estimation was related to driving ability in that persons who overestimated on a cognitive estimation task overestimated driving skill, but it was not related to accuracy of predictions or postdictions of driving skill. The findings together suggest that stroke survivors may benefit from interventions to improve awareness of deficit.

However, the generalizability of the findings is limited by the relatively small sample size and relatively low power. Furthermore, the large number of tests that were run increased experiment-wise alpha. On-road assessment is the gold-standard for driving evaluation and the design of the study could have been improved if survivors completed an on-road evaluation in addition to the driving simulator. Although the simulator and driving scenarios were designed to be life-like, driving in the simulator was a novel experience for the participants and it may be that their estimates of performance would have been different if they were driving on-road. Another limitation of this study is the characteristics of the present sample who were, on average, younger than typical stroke survivors who may have had multiple strokes. A larger sample of survivors and the inclusion of other neurologically impaired populations would likely improve generalizability. Future research should examine the relationship between training on the driving simulator and on-road driving assessments to evaluate if there is temporal stability of increased awareness of driving ability.

APPENDIX A

Table 1. Demographic Statistics for Stroke Survivors (*N* = 54).

Variable	*M*	*SD*	Range
Stroke Survivors			
Age (years)	55.6	(9.7)	32 – 81
Education (years)	14.1	(2.4)	9 – 20
Percent Men	54.5		
Percent Right Handed	96.3		
Location of stroke (%)			
Left	51.9		
Right	33.3		
Bilateral or other	14.8		
Percent driving	61.1		
Time since stroke (months)	44.3	(75.3)	3 - 328

Table 2. Demographic Statistics of Survivors who Completed the Simulator and Did Not Complete the Simulator.

	Group			
	Survivor Simulator Completers (*n* = 50)		Survivors Simulator Incomplete (*n* = 4)	
Variable	*M*	*SD*	*M*	*SD*
Age (years)	55.4	10.0	58.5	4.4
Education (years)	13.9	2.3	16.3	1.3
Percent Male	58.0		25.0	
Percent Right Handed	96.0		100.0	
Laterality				
Left	50.0		75.0	
Right	34.0		25.0	
Bilateral/other	16.0		0	
Time since stroke (months)	45.5	78.2	29.3	14.7
Percent driving	60.0		75.0	

Table 3. Descriptive Statistics for the Awareness Groups (Intact *n* = 34, Impaired *n* = 20) and the Total Sample (*N* = 54).

	Group			
	Intact (*n* = 34)	Impaired (*n* = 20)	Total (*N* = 54)	
	M (SD)	*M (SD)*	*M (SD)*	*Range*
Awareness Questionnaire (AQ):				
Self-report:				
Total Score	25.2 (6.2)	38.0 (13.6)	29.9 (11.4)	16.0 – 68.0
Cognitive Subscale	1.5 (0.5)	2.3 (0.9)	1.8 (0.8)	0.7 – 4.0
Behavioral/Affective Subscale	1.6 (0.5)	2.3 (0.8)	1.9 (0.7)	0.5 – 4.0
Motor/Sensory Subscale	1.4 (0.5)	2.1 (0.9)	1.6 (0.7)	0.3 – 4.0
SO-report on survivor:				
Total Score	28.5 (7.4)	19.3 (8.3)	24.2 (7.9)	8.0 – 39.0
Cognitive Subscale	1.7 (0.5)	1.1 (0.5)	1.4 (0.5)	0.1 – 2.1
Behavioral/Affective Subscale	1.8 (0.6)	1.3 (0.6)	1.6 (0.6)	0.3 – 3.3
Motor/Sensory Subscale	1.4 (0.4)	1.1 (0.5)	1.6 (0.5)	0.5 – 2.0
AQ Discrepancy Total	-0.2 (0.4)	1.1 (0.6)	0.3 (0.8)	8.0 – 39.0
AQ Discrepancy - Cognitive	-0.2 (0.4)	1.2 (0.7)	0.3 (0.9)	0.1 – 2.1
AQ Discrepancy - Motor/Sensory	-0.03 (0.5)	1.0 (0.7)	0.4 (0.8)	0.3 – 3.3
AQ Discrepancy - Behavioral/Affective	-0.3 (0.6)	1.1 (0.7)	0.2 (0.9)	0.5 – 2.0
Simulator:				
Simulator Overall (T Score)	38.5 (11.0)	33.6 (15.4)	36.7 (12.9)	2.0 – 59.8
Simulator Prediction	50.2 (6.7)	54.2 (8.4)	51.7 (7.6)	37.5 – 67.5
Simulator Postdiction	46.7 (5.4)	50.1 (7.7)	48.0 (6.5)	40.0 – 62.5
Simulator Prediction Accuracy	11.7 (11.0)	21.3 (17.3)	15.3 (14.3)	-8.2 – 64.7
Simulator Postdiction Accuracy	7.5 (10.2)	18.4 (13.9)	11.5 (12.8)	-12.0 – 49.7

Table 4. Descriptive Statistics and Comparisons of Survivors with Intact (*n* = 34) and Impaired (*n* = 20) Awareness of Abilities.

	Group					
	Intact Awareness (*n* = 34)		Impaired Awareness (*n* = 20)		*F(1,52)* or $X^2(1)$	*p*
Variable	*M*	*SD*	*M*	*SD*		
Age (years)	55.3	9.0	56.1	11.0	0.09	.77
Education (years)	13.9	2.6	14.5	1.9	0.87	.36
Percent Male	52.9		60.0		0.25	.61
Percent Right Handed	100.0		90.0			
Laterality					0.55	.76
Left	50.0		55.0			
Right	35.3		30.0			
Bilateral/other	14.7		15.0			
Time since stroke (months)	44.5	72.7	43.8	81.7	0.00	.97
Percent driving	64.7		55.0		0.72	.40

Table 5. Demographic Statistics for Stroke Survivors' Significant Others (*N* = 54).

Variable	*M*	*SD*	Range
Significant Others			
Age (years)	46.6	(14.1)	18 - 72
Education (years)	13.9	(2.3)	10 – 20
Percent Men	29.6		
Percent Right Handed	92.6		
Kinship (%)			
Spouse/Romantic Partner	49.1		
Adult Child	21.3		
Parent	3.7		
Other Family	15.7		
Friend	8.3		
Percent driving	100		

Table 6. Correlations: Driving Simulator Performance, Ratings of Abilities, and Awareness of Deficit for Stroke Survivors (*N* = 54).

	Simulator Actual Performance	Simulator Predicted	Simulator Postdicted	Accuracy of Predicted Performance	Accuracy of Postdicted Performance
Simulator Predicted	.21†	--	--	--	--
Simulator Postdicted	.33**	.45**	--	--	--
Awareness of deficit: AQ Difference Total	-.31*	.22†	.22†	.42**	.49**
AQ Difference - Cognitive	-.33**	.17	.17	.41**	.48**
AQ Difference - Behavioral/Affective	-.18†	.25*	.28*	.31**	.37**
AQ Difference - Motor/Sensory	-.40**	.20†	.14	.49**	.53**

Note. AQ = Awareness Questionnaire, Total score, and Cognitive, Behavioral/Affective, and Motor/Sensory domains; AQ Difference = (Survivor self-report) – (SO-report on survivor). Accuracy of predicted performance = (Predicted performance – Actual simulator performance); Accuracy of postdicted performance = (Postdicted performance – Actual simulator performance). † $p < .10$, *$p < .05$, **$p < .01$.

Table 7: Hierarchical Multiple Regression Analysis Predicting Performance on the Driving Simulator.

Variable	R^2	Beta	sr^2	*F*	*df*	*p*	R^2 Change	Sig *F* Change
Model 1	.10			2.54	2,47	.09	--	---
Age		-.24						
Stroke Severity		.22						
Model 2	.34			4.41	5,47	.003	.24	.004
Age		-.23	.07					
Stroke Severity		.18	.04					
AQ Cog Diff		-.24	.02					
AQ Beh Diff		.44	.10					
AQ Mot Diff		-.52	.12					

Note. sr^2 (unique) = squared semipartial correlation; AQ Cog Diff = AQ Patient Cognitive Subscale – Significant Other Cognitive Subscale; AQ Beh Diff = AQ Patient Behavioral/Affective Subscale – Significant Other Behavioral/Affective Subscale; AQ Mot Diff = AQ Patient Motor Subscale – Significant Other Motor Subscale. $^{\dagger}p$ <.10, *p < .05. **p < .01.

Table 8. Correlations: Driving Simulator Performance and Ratings of Abilities for Stroke Survivors with Intact (*n* = 34) and Impaired (*n* = 20) Awareness of Deficit.

	Simulator Actual Performance			Simulator Predicted			Simulator Postdicted			Accuracy Predicted Performance			Accuracy Postdicted Performance		
	Total	Intact	Impaired	Total	Intact	Impaired	Total	Intact	Impaired	Total	Intact	Impaired	Total	Intact	Impaired
Simulator Predicted	.21†	.32*	.21	--	--	--	--	--	--	--	--	--	--	--	--
Simulator Postdicted	.33**	.29†	.53*	.45**	.42*	.41*	--	--	--	--	--	--	--	--	--
Self-rated abilities (AQ)															
Total score	-.22†	-.15	-.14	.24*	.27†	.03	.16	.11	-.01	.33**	.31*	.13	.34**	.24†	.11
Cognitive	-.24*	-.07	-.25	.14	.17	-.09	.10	-.02	-.03	.30*	.17	.17	.33**	.08	.20
Behavioral/Affective	-.07	-.13	.14	.30*	.19	.21	.19†	.19	-.01	.22†	.25†	-.04	.21†	.23†	-.14
Motor/Sensory	-.29*	-.17	-.28	.23*	.34	-.01	.18	.14	.03	.40**	.38*	.24	.43**	.32*	.28
SO-rated abilities (AQ)															
Total score	.19	.15	.09	-.04	.28†	-.08	-.13	.10	-.10	-.23*	-.02	-.16	-.30*	-.05	-.15
Cognitive	.17	.10	.07	-.08	.12	.00	-.12	-.03	.05	-.22†	-.03	-.10	-.28*	-.08	-.09
Behavioral/Affective	.16	.06	.14	-.01	.27†	-.09	-.18†	.07	-.24	-.18†	.10	-.20	-.27*	.04	-.27
Motor/Sensory	.21†	.32*	-.02	.03	.42**	-.19	-.20†	.37*	-.06	-.20†	-.17	-.11	-.21†	-.14	.04

Note. SO-rated = significant-other ratings of the survivor's abilities; AQ = Awareness Questionnaire. Accuracy of predicted performance = (Predicted – Actual simulator); Accuracy of postdicted performance = (Postdicted – Actual simulator) performance. † $p < .10$, *$p < .05$, **$p < .01$.

Table 9. Descriptive Statistics and Comparison for Awareness Groups (Intact *n* = 34, Impaired *n* = 17).

	Group					
	Intact (n = 34)		Impaired (n = 17)			
Cognitive Estimation	*M*	*SD*	*M*	*SD*	*t* (49)	*d*
Z - Scoring						
BCET Total	0.15	0.57	0.04	0.70	0.60	.18
BCET Quantity	0.01	0.87	0.32	1.62	-0.88	.26
BCET Weight	0.44	1.12	0.47	1.22	-0.11	.03
BCET Distance	-0.04	0.92	-0.34	0.72	1.14	.33
BCET Time	0.18	0.90	-0.28	0.74	1.83	.53
Traditional Scoring						
BCET Total	18.22	1.52	17.72	1.89	1.02	.30
BCET Quantity	4.65	0.65	4.08	0.93	2.60**	.75
BCET Weight	4.70	0.64	4.69	0.70	0.04	.01
BCET Distance	4.45	1.06	4.55	0.83	-0.31	.09
BCET Time	4.44	0.79	4.29	0.92	0.60	.17

Note: BCET = Biber Cognitive Estimation Test. Z-scoring = directional scoring. *d* = Cohen's d.
† $p < .10$, *$p < .05$, **$p < .01$.

Table 10. Correlations: Driving Simulator Performance and Ratings of Abilities for Stroke Survivors with Intact (n = 34) and Impaired (n = 17) Awareness of Deficit.

	Simulator Actual Performance			Simulator Predicted			Simulator Postdicted			Accuracy Predicted Performance			Accuracy Postdicted Performance		
	Total	Intact	Impaired	Total	Intact	Impaired	Total	Intact	Impaired	Total	Intact	Impaired	Total	Intact	Impaired
Cognitive Estimation															
BCET Total Z	.10	.06	.10	.46**	.41**	.56**	.08	.02	.21	.12	.19	.11	-.09	-.08	-.05
BCET Time	.08	-.11	.27	.23†	.17	.51*	.19†	.19	.40†	.03	.22	-.03	-.08	.11	-.12
BCET Distance	.12	.25†	-.17	.34**	.23†	.72**	-.02	-.09	.24	.06	.12	.51*	-.10	-.30*	.43*
BCET Quantity	.17	.24†	.16	.34**	.24†	.43*	-.03	-.19	.06	-.01	-10	.00	-.22†	-.39*	-.24
BCET Weight	-.11	-.18	-.03	.22†	.34*	.03	.08	.12	.02	.21†	.40*	.01	.18	.32*	.02
BCET Total Correct	.23*	.26†	.16	.05	-.01	.19	.16	.27†	.11	-.20†	-.27†	-.06	-.19	-.25†	.00
BCET Time	-.02	-.03	.09	.18†	.03	.60**	-.05	-.01	.01	.13	.05	.20	.01	-.03	.01
BCET Distance	.18†	.29	-.13	-.01	.09	-.35†	.13	.23	-.16	-.16	-.24	-.04	-.12	-.25	.12
BCET Quantity	.10	-.16	.16	-.11	.00	-.16	.10	.22	.07	-.17	.16	-.17	-.09	.26†	.01
BCET Weight	.28*	.31*	.36†	-.10	-.21	.02	.25*	.04	.55*	-.39**	-.46**	-.39†	-.25*	-.38*	-.19

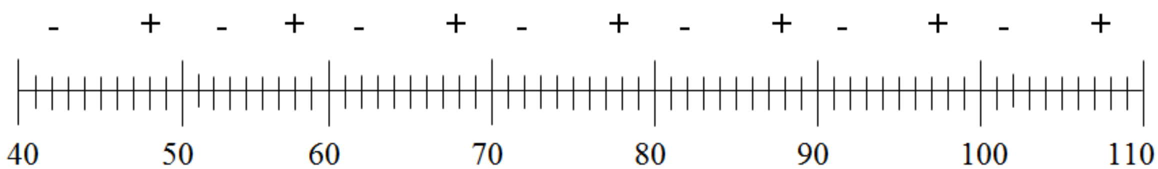
Note. BCET = Biber Cognitive Estimation Test. BCET Z = Directional scoring. BCET Correct – Traditional scoring. Accuracy of predicted performance = (Predicted – Actual simulator); Accuracy of postdicted performance = (Postdicted – Actual simulator) performance. † $p < .10$, *$p < .05$, **$p < .01$.

Table 11. Correlations of Cognitive Estimation and Ratings of Abilities for Stroke Survivors (*N* = 54) with Intact (*n* = 34) and Impaired (*n* = 20) Awareness of Deficit.

	Self-rated Total			Self-rated Cognitive			Self-rated Behavioral/Affective			Self-rated Motor/Sensory		
	Total	Intact	Impaired	Total	Intact	Impaired	Total	Intact	Impaired	Total	Intact	Impaired
Cognitive Estimation												
BCET Total - Z	.11	.41**	.03	.05	.34*	-.06	.18†	.28†	.22	.09	.37*	-.03
BCET Time	-.05	.31*	-.09	-.15	.09	-.18	.12	.46**	.10	-.09	.20	-.16
BCET Distance	-.00	.34*	-.15	.07	.48**	-.16	-.04	.16	-.14	-.07	.08	-.11
BCET Quantity	.16	.09	.12	.10	.21	-.03	.25*	-.09	.40†	.06	.09	-.04
BCET Weight	.13	.22	.09	.07	.06	.09	.08	.13	-.03	.26*	.45**	.15
BCET Total Correct	-.46**	-.35*	-.58**	-.46**	-.41**	-.51*	-.35**	-.19	-.46*	-.45**	-.19	-.66**
BCET Time	-.29*	-.10	-.51*	-.36**	-.22	-.54*	-.18†	-.08	-.31	-.20†	.15	-.56*
BCET Distance	-.14	-.33*	-.06	-.11	-.31*	.04	-.13	-.31*	-.08	-.15	-.15	-.24
BCET Quantity	-.44**	-.00	-.56**	-.43**	-.10	-.50	-.38**	.06	-.55**	-.39**	.07	-.50*
BCET Weight	-.15	-.19	-.18	-.10	-.10	-.15	-.10	-.02	-.16	-.24*	-.43**	-.18

APPENDIX B

Metacognitive Awareness of Context-Specific Cognitive Ability



F-	F	D	C	B	A	A+
Extremely Worse	Much Worse	Worse	Same	Better	Much Better	Extremely Better

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ABSTRACT

AWARENESS OF DEFICIT AND DRIVING SIMULATOR PERFORMANCE AFTER STROKE

by

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Major: Psychology (Clinical)

Degree: Doctor of Philosophy

Fifty-four stroke survivors completed a driving evaluation. Measures included predicted, postdicted, and actual performance on a driving simulator evaluation and a modified Biber Cognitive Estimation Test. Survivors nominated a significant other to serve as a knowledgeable informant about their abilities. Awareness of deficit was assessed via survivor-significant other difference scores on the Awareness Questionnaire. Five predictors (age, stroke severity, and awareness of cognitive, behavioral/affective, and motor abilities) reliably distinguished between survivors who passed and failed the driving simulator evaluation and predicted 34% of the variance in simulator prediction. Unawareness of cognitive and motor/sensory skills showed a stronger inverse relationship to driving performance than did awareness of the emotional/behavioral domain. Awareness of deficit moderated the accuracy of survivors' self-evaluations of their simulator performance (predicted and actual): Among survivors aware of their deficits, simulator prediction and postdiction scores were modestly related to actual simulator performance; among survivors unaware of their

deficits, only postdiction correlated with simulator performance. Level of awareness did not affect correlations between self-ratings of cognitive, behavioral/affective and motor/sensory abilities and actual simulator performance, predicted simulator performance, or postdicted simulator performance. Survivor self-ratings of behavioral/affective abilities were unrelated to driving simulator performance whereas self-ratings of motor/sensory and cognitive abilities were negatively correlated with driving ability. General cognitive estimation skills were positively correlated with prediction of performance on the simulator in both the aware and unaware survivor groups, with stronger prediction for the unaware participants. However, cognitive estimation scores were not related to the accuracy of self evaluations of driving skills on the simulator. Thus, stroke survivors who overestimated their cognitive and motor/sensory abilities made less accurate estimates of their driving ability and performed worse in a driving simulator than did survivors who were aware of their deficits; however, the accuracy of their self-ratings improved significantly after the simulator evaluation. This work supports research showing that awareness moderates driving ability and that awareness is multidimensional. Furthermore, the driving simulator may be a useful tool in raising survivors' awareness of their deficits as it relates to driving ability.

AUTOBIOGRAPHICAL STATEMENT

Carolyn A. Scott received her Bachelor's of Arts degree in Psychology from the University of Michigan in 2002. She is pursuing her Ph.D. in clinical psychology with a specialization in neuropsychology. Throughout graduate school, she received extensive practicum training in clinical neuropsychology at the University Health Center, Wayne State University's Psychology Clinic, and the Rehabilitation Institute of Michigan. She completed her Master's degree in March 2007: her Master's Thesis was titled *Self-assessment of driving ability and the decision to resume driving following stroke.* She has presented her findings at national and international conferences. She also has a first-author publication in a peer reviewed journal. She is currently completing her APA approved internship at the John D. Dingell VA Medical Center in Detroit and is pursuing Post-doctoral training in neuropsychology and rehabilitation psychology at the Rehabilitation Institute of Michigan in September 2010.