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Neurocognitive and socio-demographic predictors of responsiveness to an online intervention for adolescents with TBI

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Neurocognitive and socio-demographic predictors of responsiveness to an online intervention for adolescents with TBI

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Abstract

Adolescents who suffer a brain injury often have difficulty functioning in everyday settings such as school, home, and community, in part because of poor problem-solving skills. However, research on interventions and their efficacy in addressing these issues is lacking. For the current study, we examined neurocognitive and socio-demographic predictors of response to an online problem-solving intervention for adolescents with traumatic brain injury (TBI). In doing so, we aimed to identify adolescents who are most likely to benefit from this intervention, with the larger goal of being able to better tailor treatments to the individual. Adolescents who sustained a complicated mild to severe TBI and their families (N = 132) were randomly assigned to Counselor Assisted Problem Solving (CAPS), a 6-month web-based, family-centered intervention that focused on problem solving, communication, and self regulation (n = 66), or to an Internet Resource Comparison group (IRC; n = 66), a group that received a self-guided, information-based program with in-home internet access. Prior to the intervention, measures were administered to assess the behavioral functioning and neurocognitive abilities of the teen in respect to intelligence, verbal memory, and processing speed. A follow-up assessment that included the same behavioral measures was administered six months later. Linear regression was used to test the hypothesis that neurocognitive and socio-demographic factors would predict the degree of behavioral improvement associated with CAPS. Specifically, we hypothesized that lower socio-demographic status and lower neurocognitive functioning would be associated with the greatest decrease in behavioral problems following the CAPS intervention. Hypotheses were partially supported as an interaction was found among group and median family income with the Meta-Cognitive Index from the Behavior Rating Inventory of Executive Functions (BRIEF) as the dependent variable. For this interaction, lower income was associated with the greatest
decrease in behavior problems following the CAPS intervention. Additionally, a significant interaction among group and verbal intelligence was found; our hypothesis was again confirmed as lower verbal intelligence was associated with the greatest level of post-interventions behavioral improvement. By understanding factors that predict responsiveness to intervention post-TBI, clinicians will be better able to tailor treatments to the individual, thus improving the efficacy of interventions.
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Neurocognitive and Socio-demographic Predictors of Responsiveness to an Online Problem-Solving Intervention in Adolescents with TBI

Children and adolescents with traumatic brain injury (TBI) commonly experience behavior difficulties (e.g. Taylor et al. 2002; Chapman et al., 2010), stemming in part from post-injury deficits in problem-solving skills (Chevignard, 2009), which can increase behavior problems (Mazaux, 1997). Additionally, impaired self-regulation skills, which may contribute to elevations in behavior problems, have also been widely observed in those with TBI (Ganesalingam, Sanson, Anderson, & Yeates, 2006; Ganesalingam, Sanson, Anderson, & Yeates, 2007). Although post-TBI behavior problems in children have been widely researched, relatively little is known about the effects of TBI in adolescence, the efficacy of interventions to alleviate post-injury behavior and problem-solving deficits, and potential predictors of responsiveness to post-injury interventions. The current study sought to identify neurocognitive and socio-demographic predictors of response to this intervention; in doing so, we aimed to identify adolescents who are most likely to benefit from this intervention with the larger goal of being able to better tailor treatments to the individual.

Post-injury behavioral problems

Past research has documented the presence of behavior problems after pediatric TBI. Within a sample of children with moderate to severe TBI between the ages of 6 to 12 years old, Schwartz and colleagues (2003) found that children with TBI exhibited elevated levels of behavior problems relative to a cohort that sustained an orthopedic injury. These problematic behaviors were apparent in the first year post-injury and persisted long-term (up to four years post-injury). Impairments in working memory and behavior functioning were observed with these deficits tending to co-occur with unfavorable family environment. Additionally, prior
research has established an association between post-injury behavioral and functional outcomes and injury severity, with severe TBI often resulting in more substantial problems that fail to resolve over time. Children with severe TBI have been found to evidence substantial long-term functional deficits, including behavior problems (Catroppa et al., 2008; Taylor et al., 2002; Chapman et al., 2010), academic difficulties, and poorer adaptive functioning (Catroppa et al., 2008; Taylor et al., 2002). Examining predictors of long-term functional deficits, authors confirmed that injury severity, along with pre-injury functioning, are among the most robust predictors (Catroppa et al., 2008).

Post-injury neurocognitive deficits and their potential influence on behavior problems

While post-injury neurocognitive deficits have been shown to occur across multiple cognitive domains (Yeates et al., 2002), there is a growing body of literature that suggests that short-term memory, which includes impaired attention, learning efficiency, delayed recall, and accuracy in recall (e.g. DeJong & Donders, 2005; Mottram & Donders, 2005; Jacobos & Donders, 2008), and processing speed (e.g. Donders & Janke, 2008; Donders, 1997; Tremont, Mitenberg, & Miller, 1999; van der Heijden & Donders, 2003) are among the most adversely affected. Processing speed is a consistent area of impairment post-injury (Donders & Janke, 2008; Donders, 1997; Tremont, Mitenberg, & Miller, 1999; van der Heijden & Donders, 2003) with some research suggesting that the Processing Speed Index of the Weschler Scales (PSI) is the only intelligence index that is able to differentiate those with TBI from healthy controls (Donders & Janke, 2008). In contrast, measures of verbal intelligence, such as the Vocabulary subtest from the Wechsler intelligence scales, are relatively unaffected by neurological insult and may be a reliable assessment of pre-morbid neurocognitive functioning (e.g. Schmand, Smit, Geerlings, & Lindeboom, 1997; Anderson, Catroppa, Morse, Haritou, & Rosenfeld, 2000). However, other
researchers have found that verbal intelligence is affected by neurologic insult (e.g. Ewing-Cobbs et al., 1997; Verger et al., 2001).

Neurocognitive deficits post-injury are often related to injury severity and family environment, with more severe injury and lower socio-economic status associated with greater neurocognitive deficits. Comprehensively looking at post-injury neurocognitive deficits, including intellectual functioning, memory, visual-perceptual abilities, and attention-executive functions, Yeates and colleagues (2002) found that children with TBI exhibited greater short- and long-term neurocognitive impairments across the aforementioned domains relative to a control group of children with orthopedic injury. Specifically among those with severe injury, partial recovery was observed in the short-term with less persistent long-term recovery relative to those with mild to moderate TBI. This suggested that, in the case of severe injury, the bulk of expected recovery occurs predominately within the first year post-injury. Additionally, a host of socio-demographic factors, including sex, race, socio-economic status, family social stressors, and maternal education, significantly predicted post-injury neurocognitive deficits, with socio-economic status being the most robust predictor among the family factors assessed (socio-economic status, family social stressors, and maternal education). Taken together, these results suggest that socio-demographic factors, in addition to injury severity, are important when considering short- and long-term neurocognitive functioning post-injury. However, it has been posited that the relationship of socio-demographic and environmental factors may be less robust in relation to neurocognitive outcomes than in relation to behavioral and academic outcomes (e.g. Taylor et al., 2002; Catroppa et al., 2008), indicating that neurocognitive recovery may be less vulnerable to the effects of negative family environment than post-injury behavior problems (Yeates et al., 2002).
While the presence of post-injury neurocognitive deficits has been established, their subsequent effect on social and behavioral skills has yet to be widely studied. Within the TBI literature, weaknesses in working memory (Schwartz et al., 2003) and low intelligence (i.e., IQ; Catroppa et al., 2008) may have the greatest effect on persistent behavior problems. Among other pediatric clinical populations, there is also evidence of a strong relationship between neurocognitive functioning and behavioral outcomes. For example, a prominent theory regarding Attention Deficit Hyperactivity Disorder postulates that deficits in processing speed and short-term memory, which have a strong attentional component, are directly related to the development and maintenance of behavior problems. Indeed, neurocognitive deficits have been linked to behavior problems due to behavioral regulation deficits resulting from decreased attentional capabilities (Barkley, 1997). Similarly, deficits in executive functioning, which includes attentional control, are related to the maintenance of long-term behavior problems due to impaired ability to regulate attention and emotional reactions. Among children with clinical disorders, such as epilepsy (Baum et al., 2010) and conduct disorder (Morgan & Lilenfeld, 2000), executive dysfunction has been associated with the development and maintenance of behavior and socio-emotional problems.

**Potential influence of socio-demographic factors on behavior problems**

Past research in both clinical and non-clinical populations has indentified a relationship between socio-demographic factors and persistent behavior problems. When examining the relationship between socio-economic status and school violence, which included physical altercations and verbal threats, violent behavior was found to be five times higher among those of low socio-economic status relative to high socio-economic status (Boroughs, Massey, & Armstrong, 2005). Low socio-economic status has also been associated with higher levels of
adolescent behavior problems, including delinquency and aggressiveness, poorer adaptive
functioning, and greater likelihood of depression (McLoyd, 1997 as referenced in Bradley &
Corwin, 2002) and has been implicated in behavior problems related to conduct disorder (Dodge
& Pettit, 2003), childhood epilepsy (McDermott, Mani, & Krishnawami, 1995), and ADHD
(Counts, Nigg, Stawicki, Rappley, & Eye, 2005).

The relationship between family environment and the development and persistence of
behavior problems has also been demonstrated in children with TBI (e.g. Schwartz et al., 2003;
Catroppa et al., 2008; Taylor et al., 2002; Chapman et al., 2010). There is strong empirical
support for the notion that poor family environment, characterized by high levels of family
dysfunction and low socio-economic status, is related to long-term behavior problems following
pediatric TBI (e.g. Schwartz et al., 2003; Catroppa et al., 2008; Taylor et al., 2002; Chapman et
al., 2010; Yeates et al., 2010). The current literature indicates that the severity of post-injury
behavioral and adaptive functioning deficits, along with the maintenance of deficits over time, is
affected by multiple environmental factors, the most prominent being socio-economic status,
although some of the factors remained significant predictors of long-term deficits even after
controlling for SES (e.g. Yeates et al., 2004; Taylor et al, 2002; Schwartz et al., 2003). More
importantly, family environment plays a role in future outcomes and recovery, both in presence
and absence of intervention, as will next be discussed.

Post-injury predictors of recovery in the absence of intervention

Socio-demographic and family environment factors are among the most robust predictors
of post-injury recovery in the absence of intervention (e.g. Taylor et al., 2002; Catroppa et al.,
2008; Yeates et al., 2002; Chapman et al., 2010; Schwartz et al., 2003; Yeates et al., 2004;
Yeates et al. 2010; Taylor et al., 2001). In the absence of intervention, poor family environment,
which includes low socio-economic status, poor family functioning, and high family stress, has been associated with less recovery of social skills (Yeates et al., 2004; Taylor et al., 2002), academic functioning (Taylor et al., 2002), and behavioral functioning (Schwartz et al., 2003; Chapman et al., 2010). Injury severity (Catroppa et al., 2008) and permissive parenting style (Chapman et al., 2010) have also been implicated in long-term behavior problems with injury severity suggested to be the most highly predictive factor (Catroppa et al., 2008). Furthermore, authors have reported an interaction between injury severity and socio-economic status (e.g. Yeates et al., 2002), with greater effects of SES among certain subgroups of children with TBI.

Recent research on recovery following TBI in young children with TBI has confirmed the deleterious effects of disadvantaged social environment on recovery with the negative effects of a poor family environment were most pronounced following a mild to moderate injury with the negative effects seeming to lessen over time among those with severe TBI (Yeates, Taylor, Walz, Stancin, & Wade, 2010).

Despite mounting evidence that socio-demographic factors have a significant role in post-injury recovery in the absence of intervention, research has yet to adequately address the underlying mechanism(s) through which such factors operate. It has been suggested that advantaged family environments may mediate neural reorganization post-injury, thus facilitating more efficient recovery (Taylor et al., 2002). Taylor and colleagues further postulated that advantaged family environment may offer more opportunities for greater behavioral adjustment and acquisition of compensatory skills. In contrast, disadvantaged families likely have stressors beyond those related to the injury that may be less common or less disruptive in advantaged families. Offering support for this notion, disadvantaged family environment has been demonstrated to be related to high levels of family dysfunction, less effective child management
strategies, and greater frequency of negative interactions (e.g. Spieker, Larson, Lewis, Keller, & Gilchrist, 1999). Disadvantaged families are also likely to have less resources, be it time, money, or otherwise, to invest in their child’s recovery. Taken together, it may be that disadvantaged families do not have resources to invest in the facilitation of efficient recovery, indicating that behavioral recovery post-injury is closely tied to the quality and quantity of environmental resources available.

Receiving far less attention within the current TBI literature is the idea that neurocognitive ability may predict behavioral recovery after neurological insult. The Cognitive Reserve Hypothesis provides a potential explanation of the role of neurocognition in post-injury recovery. Cognitive Reserve Hypothesis states that high levels of pre-morbid neurocognitive functioning may aid in preserving functional capacity after neurologic insult (Kesler, Adams, Blasey, & Bigler, 2003). Other authors have described cognitive reserve as the ability to the efficiently utilize existing brain networks or to elicit the use of alternative networks to implement new cognitive strategies (Stern, 2003). Cognitive reserve has been studied in relation to a variety of clinical disorders, such as dementia (e.g. Roe, Xiong, Miller, Morris; 2007; Stern, 2006) and HIV-related cognitive decline (e.g. Stern, Silva, Chaisson, & Evans, 1996). Within the dementia literature, for example, high pre-morbid neurocognitive functioning is associated with reduced dementia-related pathology, such as memory loss, and a less precipitous decline in cognitive ability (e.g. Roe, Xiong, Miller, & Morris, 2007; Stern, 2006). In one of the few studies examining cognitive reserve in TBI, Kesler and colleagues (2003) found that pre-injury educational level, but not pre-injury standardized testing, partially predicted post-injury outcome, therefore offering support for the notion that pre-injury cognitive reserve may blunt the negative effects of TBI. According to the Cognitive Reserve Hypothesis, among those who have not
sought post-injury intervention, one would expect low pre-morbid neurocognitive functioning along with neurological insult or trauma to result in higher levels of behavioral dysfunction in comparison to those with high pre-morbid neurocognitive abilities who experience a trauma of similar magnitude.

*Current interventions for post-injury behavior problems*

Given the presence of neurocognitive deficits following TBI, a problem-solving intervention alone may be unlikely to result in clinically significant improvements. In the case of TBI, it is often necessary for individuals to re-learn attentional control skills to increase ability to implement self-regulatory behaviors. Therefore, effective behavioral interventions must emphasize skills to organize the external environment to provide support and reinforcement for desirable behaviors (Feeney & Ylvisaker, 2003). Feeney and Ylvisaker (1995; 2003) emphasized the role of ongoing environmental structure and implementation of mechanisms to encourage behavioral control as a means of fostering post-injury recovery of cognitive, social, and behavioral functioning. Those with TBI would also be expected to benefit from consistent behavioral and cognitive routines as a means of facilitating the development of independent problem-solving and functioning across day-to-day settings (Feeney & Ylvisaker, 1995; 2003). Other authors have further suggested that interventions that are family-based serve to reduce conduct problems by improving communication and relationships between family members, which in turn increases social competence (Kumpfer & Alvarado, 2003). Taken together, there is a theoretical basis to suggest that a family-centered approach that targets the functioning of both the injured child and the family may be an effective means of working to alleviate post-injury behavior problems.
Researchers have begun to recognize the current lack of interventions that are tailored to meet the specific needs of those with TBI and their families. A series of recent studies points to the efficacy of online, problem-solving interventions for use with individuals with TBI (Wade, Carey, & Wolfe, 2006; Wade et al., 2010). The Online Family Problem-Solving intervention, which included self-guided portions in addition to live videoconferencing with a therapist, has been shown to be efficacious in reducing behavior problems and increasing self-regulation. Relative to a demographically matched cohort who received only internet-based resources concerning TBI, the intervention group exhibited significantly greater parent-reported self-management, compliance with parental request, social competence (Wade, Carey, & Wolfe, 2006), improved executive functioning (Wade et al., 2010), and significant improvements in parental ratings of their own injury-related burden, psychiatric symptoms, depression, and parenting stress (Wade, Wolfe, Brown, & Pestian, 2005; Wade, Carey, & Wolfe 2006b). Overall, these studies show that a family-based, problem-solving intervention may address many of the day-to-day deficits that result from TBI. Additionally, the online aspect makes these interventions cost-efficient and offers personally relevant services to people that might not otherwise have access to interventions, such as those living in rural communities.

Predictors of response to intervention

Consistent with much of the TBI literature investigating recovery in the absence of intervention, injury severity is a significant predictor of responsiveness to intervention. For recovery of neurocognitive abilities, Wade and colleagues (2010) found that post-intervention improvements in executive functioning abilities were more pronounced among those who sustained a more severe injury or reported more severe executive functioning deficits prior to the intervention. However, contrary to what might be expected, Wade, Carey, and Wolfe (2006)
found no evidence of differential treatment efficacy as a function of injury severity when examining the persistence of behavior problems after an online family problem-solving intervention.

Wade and colleagues (2010) found that low socio-economic status was associated with greater short-term responsiveness to an online family problem-solving intervention, as evidenced by reduced behavior problems. As previously discussed, researchers have postulated that disadvantaged families are less likely to be able to provide a rich environment to facilitate efficient recovery and are likely to have greater stressors, beyond injury-related concerns, relative to advantaged families (Taylor et al., 2002). While such concerns would be expected to exist within all families, they often exist to a greater degree in disadvantaged families (Spieker, Larson, Lewis, Keller, & Gilchrist, 1999). Wade and colleagues (2006) present a similar argument when explaining the relationship between socio-demographic factors and response to intervention by suggesting that more advantaged families are able to offer a richer environment to facilitate recovery in the absence of outside interventions. In contrast, disadvantaged families likely have greater stressors, in addition to those related to the injury, less available resources to invest in their child’s recovery (Wade et al., 2006), and less problem-solving skills (Wade, Walz, Carey, & McMullen, in press). The potential for less efficient recovery due to poorer environment and greater stressors, both injury related and non-injury related, means that disadvantaged families may have more unresolved issues to address during the intervention and are more likely to benefit from the intervention.

Research has yet to investigate the role of neurocognitive factors as a predictor of responsiveness to post-injury interventions. To our knowledge, cognitive reserve has only been investigated in the context of pre-morbid functioning as a predictor of cognitive recovery in the
absence of intervention after neurological insult. However, the cognitive reserve framework may help to explain the role of socio-economic status in responsiveness to post-injury interventions. Given that poor family environment is associated with greater response to the intervention, one may then expect for neurocognitive deficits to function in a similar fashion. That is, those who have lower neurocognitive functioning may experience substantial long-standing behavior problems, resulting from the effects of neurocognitive deficits on problem-solving abilities. Therefore, low levels of neurocognitive ability would be associated with greater response to a family-based, problem-solving intervention. However, the Cognitive Reserve Hypothesis posits that higher levels of neurocognitive functioning are protective against the negative effects of TBI. Therefore, despite evidencing fewer gains in response to intervention, we expect that individuals with higher neurocognitive functioning will experience fewer injury-related behavior deficits relative to those with lower neurocognitive functioning.

Besides neurocognitive and socio-demographic factors, there is evidence that factors relating to the therapy process may additionally contribute to our understanding of influences on responsiveness to interventions. Among these factors, adherence may be of particular relevance for internet-based interventions. Using an online, family-based problem-solving intervention that included web-based resources and videoconferencing with a therapist for children who sustained a TBI, Carey, Wade, and Wolfe (2008) found that the caregiver’s comfort and familiarity with the use of technology significantly predicted adherence to the intervention. For those families who were less familiar with or had less experience with computers, adherence to the program was significantly less, resulting in fewer post-intervention improvements of parental symptoms of anxiety and depression. These results suggest that adherence may significantly affect
responsiveness to post-injury interventions, with this consideration greater when using internet-based interventions.

Similar findings have also been shown with interventions delivered in a traditional, non-web based format. In a meta-analysis of predictors of response to interventions for externalizing behavior problems in children, predictors included parental education, severity of pre-intervention behavior problems, and maternal psychopathology. The most salient factor identified was family income, with low socio-economic status families less likely to complete the intervention (Reyno & McGrath, 2006). In the case of a combined behavioral and medication treatment for pediatric ADHD, lower socio-economic status was associated with greater non-adherence and poorer treatment response (Rieppi et al., 2002). Similarly, when examining predictors of non-completion of a program aimed at reducing behavior problems and family conflict in children with antisocial behavioral problems, higher family adversity and lower socio-economic status were associated with higher drop-out rates (Prinz & Miller, 1994).

Current study

Given the dearth of evidence-based, behavioral interventions for adolescent TBI (e.g. Warschausky, Kewman, & Kay, 1999; Feeney & Ylvisaker, 2003), a critical need exists for research that addresses (1) the needs of adolescents with TBI, (2) family-based treatment approaches that target day-to-day deficits in problem-solving, and (3) predictors of who is likely to benefit from a particular intervention thereby facilitating the tailoring of treatments based on individual factors. Shari Wade, Ph.D., co-mentor for the proposed project and PI of the parent project, is conducting an ongoing investigation of the efficacy of problem-solving training for improving outcomes in adolescents who have sustained a moderate to severe TBI. Counselor Assisted Problem Solving (CAPS) integrates a problem-solving heuristic with information and
skills relevant to recovery from adolescent TBI, with the additional advantage of utilizing the Internet to deliver cost-effective and personally relevant mental health services.

In the current study, we examined whether neurocognitive and socio-demographic factors predicted response to the CAPS intervention. While past research has not specifically examined neurocognitive functioning as a predicator of response to intervention, it has shown that, relative to those with mild or moderate injuries, children with more severe injuries benefit more from problem-solving interventions (Wade et al., 2010). Compared to those from more economically advantaged homes, children from disadvantaged homes demonstrated less cognitive and behavioral recovery post-injury (Taylor et al., 2002) and greater responsiveness to interventions (Wade, Carey, & Wolfe, 2006). Overall, the literature indicates that those who experience greater deficits, whether as a result of environmental stress or greater neurological insult, demonstrate a greater response to interventions.

_Hypothesis 1:_ Performance on neurocognitive measures will predict behavioral gain following the CAPS intervention with adolescents with lower neurocognitive functioning demonstrating greater improvement. Similarly, median income and primary caregiver education will predict short term (six-month) behavioral gains following the CAPS intervention, with adolescents with lower income and caregiver education demonstrating greater improvement.

_Hypothesis 2:_ In addition to the neurocognitive and socio-demographic factors, adherence to the intervention will account for a significant amount of the variance in the post-intervention behavioral ratings. Specifically, we expect that greater adherence will be associated with greater effects of the intervention, as assessed by decreased behavior problems.

Method

*Participants*
The parent study, funded by the National Institute of Mental Health and the Colorado Brain Injury Trust Fund, is being conducted at five major trauma-centers: Cincinnati Children’s Hospital, MetroHealth Medical Center (Cleveland, OH), Rainbow Babies & Children’s Hospital (Cleveland, OH), the Children’s Hospital of Colorado (Denver, CO), and the Mayo Clinic (Rochester, MN). 132 children aged 12-17 years who were hospitalized over night for a complicated mild to severe TBI (defined by the Glasgow Coma Scale rating; GCS) within the previous 1-6 months and their families were initially recruited. Eligibility requirements included alteration of neurological functioning as measured by a GCS score less than 13 or evidence of neurological insult as seen on magnetic resonance imaging or computerized tomography, English as the primary language spoken in the home, availability of the adolescent to participate in the intervention, and the family residence being within a 3-hours drive of the hospital.

**CAPS intervention**

As part of the ongoing parent study, an initial baseline assessment at the family’s home was completed by study personnel; at that time, the primary caregiver completed measures that assessed the functioning and behavior of the teen along with relevant demographic information. Neurocognitive measures of intelligence, working memory/attention, and processing speed were administered to the adolescent. A follow-up assessment was completed six months post-baseline that included the same behavioral assessments that were completed at baseline. All families were provided with a new computer and high speed internet access and randomly assigned to one of two internet-based interventions: CAPS, a 6-month web-based, family-centered intervention that focuses on problem solving, communication, and self regulation, or to an internet resource comparison group (IRC), a comparison group that received a self-guided, information-based program. For those in the CAPS group, the family received instructions and a
demonstration of how to access the available treatment modules and instructions as to how the individual sessions with the therapist will be conducted via online videoconferencing.

Each CAPS session consisted of a self-guided online portion providing didactic content regarding problem-solving skills, video clips modeling this skill, and exercises and assignments that provide the family with opportunities to practice the new skill. New material was released upon completion of each online session with the therapist. Online videoconference sessions with the therapist were scheduled biweekly for the first three months of the intervention, for a total of six sessions. During these sessions, the therapist reviewed the online materials and practiced the problem-solving process using a problem that the family identified.

The individualized portion occurred during months four and five of the intervention. As part of the sixth online session, participating parents completed a measure of family burden and a self-assessment of problem solving and communication. Using an algorithm, the therapist planned individualized sessions for the family with ongoing attention given to injury-related issues that were identified on the questionnaires. Up to two therapist sessions per month in months 4 and 5 were scheduled to address unresolved issues, for a maximum of four individualized sessions, in addition to the therapist contact that occurred every two weeks. All families were scheduled for one session with the therapist in the sixth month.

Measures

Information regarding injury severity was collected from relevant hospital records; socio-demographic information, including median family income and primary caregiver educational attainment, was collected from the caregiver at the baseline assessment. Also at baseline, neurocognitive measures of general intelligence, verbal memory, and processing speed were administered. These measures were selected because these domains are known to be commonly
affected by TBI and reliably discriminate TBI from control participants (e.g. Jacbos & Donders 2008; Mottram & Donders, 2005; van der Heijden & Donders, 2003). Finally, parents completed measures about the adolescent’s behavior at baseline and the six month follow-up assessment. These behavior measures were selected based on prior research that demonstrated that these measures are sensitive to social and behavior problems often found in pediatric clinical populations.

The 2-scale version of The Wechsler Abbreviated Scale of Intelligence (WASI) is a screening measure that has been shown to provide a reliable estimate of Full Scale IQ, as measured by the Wechsler Adult Intelligence Scale- III (WAIS-III; Psychological Corporation, 1997) and Wechsler Intelligence Scale for Children-IV (WISC-IV; Psychological Corporation, 2003). The WASI has the added advantage of reduced participant burden as it takes less time to administer. The 2-scale version of the WASI consists of the Vocabulary subtest, a measure of basic word knowledge, and the Matrix Reasoning subtest, a measure of analytical reasoning abilities. The Vocabulary subtest of the WASI is similar to that found on the WISC-III and the WAIS-III except that the WASI includes low-end picture items that are not found on the WISC-III or the WAIS-III. In validation studies of the WASI, the Vocabulary subtest has been shown to provide a reliable estimate of the Verbal Intelligence Quotient obtained from the WISC-III or the WAIS-III (Psychological Corporation, 1999). Specific to the current investigation, verbal intelligence has been suggested to be a reliable estimate of pre-morbid ability (Lezak, Howieson, & Loring, 2004), thus allowing for the investigation of questions concerning cognitive reserve and response to CAPS.

The California Verbal Learning Test- 2nd Edition (CVLT-II; Delis, Kaplan, Kramer, & Ober, 2000) is a repeated list-learning measure that requires the use of multiple neurocognitive
abilities, including short-term memory, attention, working memory, long-term memory, and executive functions. The CVLT was selected for use in the current study because it has been shown to be sensitive to the neurocognitive effects of TBI (e.g. Jacobs & Donders 2008; DeJong & Donders, 2009; Mottram & Donders, 2005). Research investigating the construct validity for the CVLT-II has shown that it is able to comprehensively quantify short-term memory abilities as it provides information regarding learning strategies, acquisition rate, serial position effect, discriminability, and learning interference (Delis, Freeland, Kramer, & Kaplan, 1988). Specific to TBI, Jacobs and Donders (2008) found that adults with TBI exhibited impaired performance on the CVLT with short-term memory deficits marked by rapid forgetting. Also within a sample of adults with TBI, a confirmatory factor analysis indicated a four-factor model of post-injury deficits captured by the CVLT-II: deficits in attention, learning efficiency, ability to recall information after a delay, and ability to accurately recall information (DeJong & Donders, 2009). Within a sample of children who were administered the children’s version of the CVLT, these same four factors were found by using similar statistical methodology (Mottram & Donders, 2005). Administration of the CVLT consists of five free recall trials in which the same list of words were read prior to each trial with the participant asked to recall the words in any order. After the five learning trials, an interference list is presented, at which time the participant had a single trial to recall the words from the interference list. Without any cuing, the participant is then asked to recall the words from the original list and is cued with semantic categories (e.g. words that are furniture, vegetables, ways of traveling, or animals). After a twenty minute delay, the participant is administered a single free recall trial to recall the original list, cued with semantic categories, and presented with a recognition trial in which a longer list of words is read and the participant is prompted to determine if each word was a member of the original. For the
current study, we used total recall during the initial five learning trials as a measure of short-term memory/attention (DeJong & Donders, 2009).

The Processing Speed Index (PSI), which consists of the Coding and Symbol Search subtests of both the Wechsler Adult Intelligence Scale-IV (WAIS-IV; Psychological Corporation, 2008) and Wechsler Intelligence Scale for Children-IV (WISC-IV; Psychological Corporation, 2003) has been utilized in the assessment of pediatric clinical populations, such as Attention-Deficit Hyperactivity Disorder (Shanahan et al., 2006) and Pervasive Developmental Disorders (Scheuffgen, Happee, Anderson, & Frith, 2000). For the assessment of TBI, the PSI has been shown to be a consistent area of impairment. Although there is no classic intelligence profile associated with TBI, to demonstrate a relative strength on PSI is uncommon (van der Heijden & Donders, 2003). PSI has been shown to be the only index that significantly differentiated children with TBI from healthy controls (Donders & Janke, 2008; Donders, 1997; Tremont, Mittenberg, & Miller, 1999, indicating that the PSI has acceptable criterion validity for the assessment of individuals with TBI (Donders & Janke, 2008).

Since behavior problems are among the most troubling and prevalent consequences of TBI (e.g. Schwartz et al., 2003; Chapman et al., 2010), measures of behavior problems are the primary dependent variables. Parents completed the Behavior Rating Inventory of Executive Function (BRIEF; Gioia, Isquith, Guy, & Kenworthy, 2000), a rating of the adolescent’s executive functioning abilities. This measure has been demonstrated to have high levels of internal consistency and stability and acceptable levels of both inter-rater and test-retest reliability. From the BRIEF, we used the Meta-Cognitive Index (MI), a measure of the adolescent’s ability to initiate, plan, organize, and sustain future-oriented problem-solving
behaviors, self-manage one’s behavior while completing a task, and monitor one’s own performance (Gioia, Isquith, Guy, & Kenworthy, 2000).

The Child Behavior Checklist (CBCL; Archenbach & Rescorla, 2000; 2001) is a parent report measure that focuses on problematic behaviors in day-to-day family, social, and school situations. Research has shown that the CBCL has high test-retest reliability and criterion validity (Archenbach & Rescorla, 2000; 2001) and is sensitive to behavior problems following TBI (e.g. Taylor et al., 2002; Schwartz et al., 2003). For the current investigation, the Externalizing Behavioral Problems and Internalizing Behavioral Problems subscale scores from the CBCL were used to provide parent perspectives on the adolescent’s behavior problems.

The Child Adolescent Functional Assessment Scale (CAFAS; Hodges, 1999) is a clinical rating conducted by an interviewer in which the adolescent’s functioning is assessed across the following domains: school, home, community, behavior toward others, mood/emotions, self-harmful behaviors, substance use, and thinking. The CAFAS has been shown to reliably detect functional and behavior problems in adolescents across a variety of contexts and domains (Hodges, 1999). For the purposes of the current study, we will be utilizing the CAFAS Total Score, which is a summary score of the domains assessed.

**Statistical Approach**

Linear regression was used to examine the interaction of treatment group with socio-demographic and group with neurocognitive factors in relation to parental ratings of the adolescent’s behavior at six-months, after controlling for baseline ratings of behavior and injury severity. To assess injury severity, participants were divided into groups based on conventional criteria using the Glasgow Coma Scale (GCS; Jones, 1979) as having sustained a complicated mild to moderate (GCS 9-12 or GCS > 12 with abnormal imaging as assessed by magnetic
resonance imaging or computerized tomography) or severe (GCS ≤ 8) injury. Seven participants did not have available GCS scores; for these seven participants, a neuropsychologist determined if the injury was complicated mild, moderate, or severe based on length of coma. For this reason, GCS scores for all participants were coded as complicated mild, moderate, or severe and the categorical injury severity variable was used in all analyses. Initial models were first calculated that examined the independent effects of each measure of neurocognitive functioning and socio-demographic status using six-month behavioral reports as the dependent variable and baseline parent reports of behavior and injury severity as covariates. The neurocognitive and socio-demographic factors were treated as continuous variables with the six-month CBCL Externalizing and Internalizing Behaviors subscales, CAFAS Total score, and BRIEF Meta-Cognitive Index (MI) used as separate dependent measures.

Our primary hypothesis stated that lower socio-demographic status (median family income and primary caregiver educational attainment) and lower neurocognitive functioning (Vocabulary, Matrix Reasoning, PSI, and CVLT) would be associated with greater improvements in behavior following CAPS at the six-month assessment, controlling for baseline behavior and injury severity. Thus, it was hypothesized that post-intervention behavior problems would vary as a function of treatment group, neurocognitive functioning, and socio-demographic factors, after factoring out initial differences in pre-intervention behavior problems and injury severity. See Figure 1.

Prior to calculating the regression models, interaction terms were created to allow us to test the primary hypotheses regarding whether neurocognitive functioning or socio-demographic status predicted the effects of CAPS on adolescent behavioral problems at the 6-month follow-up. To allow for ease of interpretation of the results from the regression analyses, all continuous
variables were standardized, meaning that the variables were adjusted so that the mean would be equal to zero. For the regression model examining the role of socio-demographic factors, we entered baseline behavior ratings and injury severity in the first step, median income and primary caregiver educational attainment in the second, treatment group (CAPS or IRC) in the third, and the treatment group by socio-demographic factors interaction term in the fourth. Similarly, we examined the role of neurocognitive factors using the same steps, with the only differences being entering the neurocognitive measures rather than income and education into the third step and utilizing the treatment group by neurocognitive functioning interaction terms in the fourth step.

After fitting the two models that test the independent effects of socio-demographic factors and neurocognitive variables, we tested a combined model that included the two-way interactions of group and socio-demographic factors and group and neurocognitive functioning. To make the models stable by reducing the number of terms, we first calculated individual models that included a single neurocognitive factor (Vocabulary, Matrix Reasoning, PSI, or CVLT), the socio-demographic factors (median income and caregiver education), group, and all of the two-way interactions thereof. For example, when using MI as the dependent variable, four separate models were calculated, one for each of the neurocognitive factors (Matrix Reasoning, Vocabulary, CVLT, and PSI). Within each model, baseline MI and GCS were entered in the first step, income and education in the second, the single neurocognitive factor in the third, group assignment in the fourth, and the two-way interactions (group x income, group x education, group x neurocognitive) in the fifth.

The models were then trimmed until a best fitting model was achieved. To trim the models, an arbitrary criterion was established such that factors with alpha levels higher than .50 were first trimmed and the models were re-calculated after each factor was removed. Once all
factors with alpha levels higher than .50 were trimmed, the factor with the highest, non-significant probability was trimmed and the model was re-calculated until only statistically significant factors remained. The factors that were found to be significant in these individual models were included in the final combined model, one model for each dependent variable. If an interaction from the fifth step was significant, all factors that comprised the interaction were included in the final combined model for that dependent variable. Unstandardized beta values were reported and used for interpretation of significant predictors. Adjusted $R^2$ and standardized beta values were reported as measures of effect size.

*Exploratory analyses*

Our second hypothesis stated that, in addition to the neurocognitive and socio-demographic factors, adherence to the intervention would account for a significant amount of the variance in the post-intervention behavior ratings. As an example to illustrate how we expected adherence to operate, when taking medications for the treatment of a medical problem, the number of pills taken would be expected to predict the relationship between pre-treatment symptoms and subsequent alleviation of symptoms. If one patient were to take the 100% of the pills as prescribed, that patient would be expected to exhibit more positive outcomes, in the form of alleviation of symptoms, relative to a patient that took only 50% of their pills. Similarly, we expected that participants that were adherent to the intervention would exhibit more positive post-intervention outcomes, in the form of improvements in behavior ratings, relative to less adherent participants. Given this conceptualization of adherence, the number of sessions completed at the six month time point was used as our primary factor of interest.

Given the scope of the current project as a thesis project, we approached this hypothesis as a preliminary investigation. In this exploratory analysis, we introduced the number of sessions
completed as an additional predictor in the regression models this time only including the CAPS participants. Similar to the approach taken for the primary analyses, we first calculated individual models; each model included a single neurocognitive factor (Vocabulary, Matrix Reasoning, PSI, or CVLT), the socio-demographic factors (median income and caregiver education), and the number of sessions completed. For example, when using MI as the dependent variable, four separate models were calculated, one for each of the neurocognitive factors (Matrix Reasoning, Vocabulary, CVLT, and PSI). Within each model, baseline MI and GCS were entered in the first step, income and education in the second, the single neurocognitive factor in the third, and the number of sessions completed in the fourth. The models were then trimmed in accordance with the procedures described above.

Results

Analysis of demographics

Of the 337 families initially identified as potentially eligible, 49 were found to be ineligible, 70 refused participation, 9 were unable to be contacted, and 77 were unable to be recruited during the initial six months post-injury, causing them to become ineligible. 132 families agreed to participate, 66 of which were randomly assigned to the CAPS group and 66 to the IRC group. Among participating adolescents, 50 had severe TBI and 82 had complicated mild to moderate TBI. See Figure 2.

Age at injury, injury severity, and race were compared between participating and non-participating families. There were no differences for age at injury between participants [mean age = 14.46 (1.72)] and non-participants [mean age = 14.68 (1.74)]. Non-participants were more likely than participants to be non-white (24.4 % to 18.2%; p < .001). For injury severity, as measured by Glasgow Coma Scale rating (GCS), there was a significant group difference
between participants and non-participants \( (p = .001) \) with non-participants [mean GCS = 11.94 (3.89)] having sustained a less severe injury than participants [mean GCS = 10.00 (4.64)].

**Preliminary analyses**

We conducted a preliminary examination of the data, first focusing on the distributions. Neurocognitive predictors (CVLT, Matrix Reasoning, Vocabulary, and PSI), caregiver education, and the behavioral reports at baseline and six-months (BRIEF MI and CBCL Externalizing and Internalizing Behaviors subscales) were normally distributed with no issues in regard to skew or kurtosis noted. The distributions of the CAFAS at baseline (skew = 0.79; kurtosis = 0.25) and six-months (skews = 1.29; kurtosis = 1.47) were skewed with the majority of the scores falling among the lower values (see Figure 3 and Figure 4). The logarithm of the CAFAS variable at baseline (skew = -0.40, kurtosis = -0.69) and six-months (skew = -0.12, kurtosis = -0.71) was calculated to improve the distribution (see Figure 5 and Figure 6).

Median income was also skewed (skew = 1.27; kurtosis = 3.39) with outliers present at the higher end of the distribution (see Figure 7). The income variable was adjusted by categorizing income into increments of $5000. The values at the extreme end of the distribution were then categorized into a grouping of median incomes of $120,000 or greater. This re-categorization of the income variable made the variable more normally distributed (skew = 0.40; kurtosis = -0.15) while also allowing for an easier and clearer interpretation of the beta values that would be calculated as part of the regression models. The re-categorized income variable also had the advantage of maintaining the continuous nature of the original income variable. See Figure 8.

While seemingly normally distributed, there were some outliers in the MI six-month data (Figure 9). Specifically, one participant scored approximately three standard deviations above
the sample mean. Examination of the data in light of the participant’s history and current level of functioning led to the determination that the high MI score was likely valid and representative of the high degree of post-injury executive dysfunction that the participant experienced. In order to reduce the effect that this extreme value might have on subsequent analyses, we placed a cap on MI scores such that scores could not exceed a T-score of 80. It was determined that among high scores, there is likely not a qualitative difference among participants who scored greater than two standard deviations above the sample mean, leading to the conclusion that a cap of 80 could be established without compromising the integrity of the data.

After assessing the distributions of the variables, we next determined if the randomly assigned treatment groups (CAPS or IRC) differed on baseline characteristics, such as injury severity, neurocognitive functioning, and socio-demographic status. Because participants were randomly assigned to either CAPS or IRC, significant group differences would not be expected. Indeed, no significant group differences were found for median income, caregiver education, injury severity, PSI, Matrix Reasoning, Vocabulary, CVLT, baseline BRIEF MI, baseline Externalizing Behaviors, and baseline CAFAS logarithm (all p’s > 0.05). A significant group difference was found on baseline Internalizing Behaviors (t (127) = 1.92, p = 0.05). Because the data analysis plan included controlling for baseline behavioral ratings, no adjustments to the data analysis plan were made. See Table 1 for means and standard deviations.

Correlational analyses were conducted to examine multicollinearity among the predictors (see Table 2). Although the literature provides no consensus for assessing multicollinearity based on correlation coefficients, it has been suggested that correlations that exceed .5 pose a risk for multicollinearity (Bonate, 1999). For the current study, correlation coefficients among the neurocognitive factors ranged from .29 to .42. While this indicated a substantial amount of
shared variance, it did not warrant concern about multicollinearity or the need to combine the neurocognitive factors into a single factor. Indeed, the correlations among the neurocognitive factors were low enough to conclude that each factor offered a unique contribution. Among dependent measures, the Global Executive Composite and Behavioral Regulation Index from the BRIEF were not utilized because they were found to be highly correlated with the CBCL Externalizing Behaviors subscale. Rather, the MI subscale from the BRIEF was used because it had a lower correlation with the other dependent measures and thus offered a unique contribution. For the dependent variables that were included in the current study, correlation coefficients ranged from .39-.59. An area of potential concern for multicollinearity was for the CBCL Externalizing subscale and CBCL Internalizing subscale ($r = .56$); however, we elected to include both subscales given evidence that they each measure distinct behavioral domains (Archenbach & Rescorla, 2000; 2001). Another area of potential concern was for the CBCL Externalizing subscale and the CAFAS logarithm ($r = .59$); we decided to include the CAFAS because we were interested including a measure that examined day-to-day functional impairments (Hodges, 1999). It has been posited that using tolerance and VIF statistics is more accurate than examining correlation coefficients when assessing for multicollinearity (Shieh & Fouladi, 2003). Therefore, we applied the criteria of Variance Inflation Factor (VIF) greater than 2.5 and tolerance less than .40 (Allison, 1999) as an indication of multicollinearity; using this criteria, no cases of multicollinearity were identified.

Initial regression analyses

We first calculated models that examined the predictive ability of neurocognitive factors without accounting for socio-demographic factors. These initial models yielded no significant findings with CVLT or Matrix Reasoning as predictors. There were also no significant findings
when considering the Internalizing subscale or CAFAS as dependent variables. A significant interaction of Vocabulary and group was found with MI scores as the dependent variable. See Table 3.

Using an analysis of simple slopes to understand the nature of the interaction among Vocabulary and group, MI scores for both the CAPS and IRC groups were estimated at one standard deviation above and below the mean for Vocabulary scores. At one standard deviation below the mean on Vocabulary, it was estimated that the difference in MI scores between CAPS and IRC was 16.76. This difference corresponded to a large effect size (\( d = 1.76; \) Cohen, 1988) and suggested that lower Vocabulary was associated with greater response to the CAPS intervention. At one standard deviation above the mean for Vocabulary scores, the difference in MI scores between the CAPS and IRC groups was 7.5 points. This difference corresponded to a moderate to large effect size (\( d = .79; \) Cohen, 1988) and was significantly smaller than the group difference among lower Vocabulary scores. However, given that the simple slopes analysis estimated values at one standard deviation above and below the means, the effect sizes are likely an overestimate and would be expected to be more modest at non-extreme values.

Results of the simple slopes analysis further indicated that the slope of the line for the IRC group (unstandardized \( \beta = -5.07; \) \( t (127) = -1.88, p = .06 \)) was marginally different from zero and that we would expect lower MI scores among those with higher Vocabulary scores. For the CAPS group (unstandardized \( \beta = -.16, \) \( t (127) = -.16, p = .87 \)), the slope of the line did not significantly differ from zero. This suggested that, among the CAPS group, MI scores did not differ based on Vocabulary scores. See Figure 10.

With the Externalizing Behaviors subscale as the dependent variable, PSI was a borderline significant predictor (\( p = .06 \)). When considering PSI as a predictor of Externalizing
Behavior scores, a small effect size (standardized $\beta = -.24$) and non-significant $R^2$ change value were found. Interpretation of the unstandardized beta value indicated that a point one increase in PSI was associated with a 2.83 decrease on the Externalizing Behaviors subscale. In no other cases were the neurocognitive factors or the interactions of the neurocognitive factors with group significant. See Table 3.

We next calculated regression models that included the socio-demographic factors without the neurocognitive factors. Results failed to yield significant findings with primary caregiver education as a predictor. Non-significant findings were found when considering the Externalizing subscale, Internalizing subscale, or CAFAS as dependent variables. For the BRIEF MI, we found a significant interaction of group x income. See Table 4.

To better understand the nature of the interaction among income and group, an analysis of simple slopes was conducted. MI scores for both the CAPS and IRC groups were estimated at one standard deviation above and below the mean for income. At one standard deviation below the mean income level, it was estimated that MI scores for the CAPS group were 12.82 points lower than that of the IRC group, suggesting that lower income was associated with greater response to the CAPS intervention. This difference is considered to be a large effect size ($d = 1.32$; Cohen, 1988). At one standard deviation above the mean, the difference in MI scores between the CAPS and IRC groups was 6.98 points, which is considered to be a medium effect size ($d = .72$; Cohen, 1988) and was significantly smaller than the group difference for the lower income estimates. Given that the simple slopes analysis estimated values at one standard deviation above and below the means, the effect sizes are likely an overestimate and would be expected to be more modest among non-extreme values.
Simple slopes analysis further indicated that the slope of the line for the IRC group (unstandardized $\beta = -5.04$, $t (128) = -1.85$, $p = .06$) differed marginally from zero, meaning that reported BRIEF MI scores depend on income values, with lower MI scores expected among those with higher incomes. The line of the CAPS group did not significantly differ from zero (unstandardized $\beta = -50$, $t (128) = -.50$, $p = .61$), which suggested that among CAPS participants, MI scores did not differ based on income level. See Figure 11.

The data analysis plan next stipulated that a combined model would be calculated in which the neurocognitive and socio-demographic factors were included in the same model. The results of these models will next be discussed.

*Meta-Cognitive Ability*

From the individual models that examined the individual predictive ability of each neurocognitive factor, none of the neurocognitive factors were significant predictors and therefore not included in the combined model. The interaction of Vocabulary and group that was significant in the model that only examined the role of neurocognitive factors was now non-significant and thus trimmed from the model. The only remaining interaction was for group and income; this interaction had a corresponding standardized $\beta$ value of .19 and a significant $R^2$ change. Similar to that which was described above, lower income was associated with greater response to the CAPS intervention. See Table 5.

*Externalizing Behaviors*

In the individual models that included a single neurocognitive factor, we found a main effect of PSI. The main effect of PSI had a small corresponding effect size (standardized $\beta = -.16$) and a significant $R^2$ change value. Examination of the unstandardized beta value indicated
that Externalizing Behaviors scores decreased 1.99 for every one point increase in PSI scores. See Table 5.

*Internalizing Behaviors*

From the individual models for each neurocognitive factor and the Internalizing Behaviors subscale as the dependent variable, no significant interactions or main effects were identified. See Table 5.

*Global Functioning*

The CAFAS was used as a measure of global functioning as it was designed to assess behavioral functioning across multiple contexts, including school, home, and in the community (Hodges, 1999). From the individual models for each neurocognitive factor and the CAFAS logarithm as the dependent variable, a significant main effect of income was observed. No interactions with group or other main effects were identified. For the main effect of income, the corresponding effect size was small (*standardized β = .24*) with a significant $R^2$ change value. Examination of the unstandardized beta values indicated that a decrease of .08 in the CAFAS logarithm occurred for every $5000 increase in income. See Table 5.

*Number of sessions completed*

In an effort to assess the role of the number of sessions completed, we first conducted a preliminary analysis of the data for the number of sessions completed. The distribution of the data indicated no issues with skew (-0.46) or kurtosis (-0.06). The distribution also showed that the majority of participants completed at least five sessions with nine participants (13.6% of CAPS group) having completed less than five sessions (Figure 12). Bivariate correlations between the number of sessions completed with the other predictors (GCS, socio-demographic factors, and neurocognitive factors) revealed correlation coefficients ranging from .003 in the
case of Matrix Reasoning to .28 in the case of CVLT. While a non-significant correlation was found between number of sessions and income ($r = .22$), it was noted that all nine of the participants that completed less than five sessions had median incomes below that of the sample mean.

We then calculated regression models that included only the CAPS group in which the number of sessions completed was introduced as a predictor. Because the aim of this exploratory analysis was to specifically examine the contribution of the number of sessions completed, interactions were not included. Results revealed that in no cases was the number of sessions completed a significant predictor of post-intervention behavior ratings ($p > .05$).

Discussion

The current study sought to identify socio-demographic and neurocognitive predictors of response to the CAPS intervention. In doing so, we aimed to offer clinicians the ability to better identify individuals who are most likely to benefit from the intervention, allowing treatments to be tailored to meet the individual needs of the adolescent and their family.

We found limited support for the hypothesis that neurocognitive and socio-demographic factors would moderate the efficacy of CAPS. Of the potential neurocognitive moderators considered, only Vocabulary significantly moderated the effects of CAPS on a single outcome of metacognitive abilities on the BRIEF. Similarly, family income moderated treatment efficacy on BRIEF-MI and none of the other behavioral outcomes. Main effects of PSI with the Externalizing Behaviors subscale as the dependent variable and income with the CAFAS logarithm as the dependent variable were found. In the exploratory analysis, we failed to find support for the role of the number of sessions completed in relation to response to
CAPS; however, these non-significant findings were likely due to limitations with the use of the number of sessions completed as a measure of adherence.

Support for Hypothesis 1

Our first hypothesis stated socio-demographic status (median income and primary caregiver educational attainment) or performance on neurocognitive measures (Matrix Reasoning, Vocabulary, CVLT, and PSI) would predict short-term (six-month) behavioral gains following the CAPS intervention. Specific hypotheses were made that lower socio-demographic status would be associated with greater improvements following the CAPS intervention. Similarly, we predicted that lower performance on neurocognitive measures (Matrix Reasoning, Vocabulary, CVLT, and PSI) would be associated with greater improvements following the intervention. Limited support for these hypotheses was found, as will next be discussed.

Meta-cognitive ability

In the models that included only the neurocognitive factors, a significant interaction of group and Vocabulary was identified with the BRIEF MI as the dependent variable. For this interaction, lower Vocabulary scores were associated with greater response to the CAPS intervention. For the significant interaction among income and group, lower income was associated with greater improvements in MI-related behavior problems following the CAPS intervention. Together, these findings supported the hypotheses that it would be the participants who were either lower functioning neurocognitively or of lower socio-demographic status that would evidence greater improvements following the CAPS intervention. However, among the dependent measures, the MI subscale was the most elevated at baseline with the other dependent measures (Externalizing, Internalizing, and CAFAS) being within the normal range. This suggested the greatest area of behavioral deficits were for MI-related behavior problems.
There is evidence both from the current study and prior research to suggest that income and verbal intelligence may share a similar, underlying construct. That is, there is reason to suspect that these two interactions may be describing a common predictor of response to the CAPS intervention. In the current study, there was a moderate, statistically significant correlation ($r = .44$) between income and Vocabulary, indicating that there is a substantial amount of shared variance between these two factors. Authors have posited that, relative to other neurocognitive abilities, verbal intelligence is highly predictive of real-world functional abilities, including academic and occupational functioning, and may be the best available estimate of cognitive reserve. In comparison to the other subtests from the Wechsler intelligence scales, the Vocabulary subtest may be the best predictor of functional ability (Walters et al., 2008) and is the most highly correlated with socio-demographic factors, such as income (Lezak, Howieson, & Loring, 2004). The relationship of verbal intelligence to socio-demographic factors has led to theorizing that cognitive reserve may be largely obtained via educational experiences with rich environments (perhaps most notably, high quality of educational environments) associated with greater cognitive reserve. Rich educational environments have also been linked to socio-economic resources with more resources associated with greater access to rich educational environments. Thus, via quality of education, cognitive reserve is thought to be indirectly tied to socio-economic resources (Stern, 2003). As a result, verbal intelligence and family income may represent the common underlying construct of quality of environment, which previous studies have shown to be predictive of recovery post-TBI both in the absence (e.g. Taylor et al., 2002; Catroppa et al., 2008; Yeates et al., 2002; Chapman et al., 2010; Schwartz et al., 2003; Yeates et al., 2004; Yeates et al. 2010; Taylor et al., 2001) and presence (e.g. Wade et al., 2006; Wade et al., 2010) of post-injury intervention.
**Externalizing behavior problems**

With the Externalizing Behaviors subscale as the dependent variable, a main effect for PSI was found with higher scores associated with fewer externalizing behavior problems. As previously noted, PSI is a consistent area of impairment post-injury (e.g. Donders & Janke, 2008; Donders, 1997; Tremont, Mittenberg, & Miller, 1999; van der Heijden & Donders, 2003) and may have profound effects on post-injury behavioral functioning. The relationship between processing speed and externalizing behavior problems has been studied in other clinical populations, perhaps most notably Attention Deficit Hyperactivity Disorder (ADHD). Authors have theorized that inefficient information processing in social and behavioral contexts is related to a reduced ability to process incoming information and integrate the newly acquired information to determine the optimal behavioral response for a given situation. That is, slow processing speed makes one less able efficiently process incoming social information and determine optimal behavioral solutions (Willcutt, 2010). In the case of TBI, post-injury externalizing behavior problems may arise from the neurocognitive effects of TBI, which include slower, inefficient processing of information, resulting in impaired behavioral regulation. In the case of PSI, it may be that abilities related to processing speed influenced the effectiveness of the CAPS intervention. This may be because, unlike verbal intelligence that may represent pre-morbid abilities, PSI is highly vulnerable to neurological insult and varies based on injury severity (e.g. Donders & Janke, 2008; Donders, 1997; Tremont, Mittenberg, & Miller, 1999; van der Heijden & Donders, 2003). Also in contrast to Vocabulary, PSI was not highly correlated with family income \((r = .19)\), suggesting that the beneficial effects of family resources and rich environments may not influence PSI.

**Global Functioning**
Family income significantly predicted CAFAS logarithm scores with higher income associated with lower CAFAS scores. This is consistent with the broader psychological literature that suggests that higher socio-demographic status is related to fewer behavior problems (e.g. Taylor et al., 2002; Spieker, Larson, Lewis, Keller, & Gilchrist, 1999; Catroppa et al., 2008; Boroughs, Massey, & Armstrong, 2005; McLoyd, 1997 as referenced in Bradley & Corwin, 2002). However, the question remains as to why a main effect of income was found for the CAFAS, but not the other dependent measures. Social and cultural norms may be such that the behaviors for which the CAFAS is sensitive to, such as drug use and theft, may be viewed as less socially deviant in lower income communities, making these behaviors more commonplace. In contrast, such behaviors may be viewed as more deviant in higher income communities, making such behaviors less common. As a result, it is difficult to determine if the behavior problems detected by the CAFAS are related to TBI or environmental factors and social and cultural norms.

Support for Hypothesis 2

Our second hypothesis stated that, in addition to the neurocognitive and socio-demographic factors, adherence to the intervention would predict short-term behavior problems following the CAPS intervention. To test this hypothesis, we sought to approximate adherence to the intervention by using the number of sessions completed. Specifically, we expected that participants that completed a greater number of sessions would exhibit more positive post-intervention outcomes relative to participants that completed fewer sessions.

The results of the current study failed to provide evidence for the hypothesis that adherence to the intervention would predict response to the CAPS intervention; in no cases was the number of sessions completed found to be a significant predictor of post-intervention
behavior ratings. As will later be discussed, there are many limitations with using the number of sessions completed to approximate adherence that likely limited out ability to accurately describe the role of adherence in response to CAPS. Perhaps the primary issue is that the number of sessions completed is a crude estimate of adherence that does not account for a multitude of relevant factors, such as time taken to complete the sessions, no-shows, cancellations, illness, vacations and/or technical difficulties. Also, the number of sessions completed variable suffered from a limited range as the maximum number of sessions possible was twelve. Finally, it may be the case that those who completed more sessions did so because they began the intervention with more severe, unresolved problems. Conversely, those who completed fewer sessions may have had fewer problems and thus found that the intervention was not necessary or relevant. While plausible, the data does not support this conjecture as the correlation between the number of sessions completed and GCS was small and non-significant ($r = -.01$). Additionally, the correlations with the number of sessions and baseline behavior ratings were small with correlation coefficients ranging from -.01 in the case of MI and Internalizing Behaviors to -.27 in the case of the CAFAS. These correlations suggest that the number of sessions completed is unrelated to baseline levels of distress.

Evidence for cognitive reserve

One of the primary ideas of interest in the current investigation was the application of Cognitive Reserve Hypothesis to post-injury response to intervention. Cognitive Reserve Hypothesis states that a high level of pre-morbid neurocognitive ability buffers the effects of neurological insult. Cognitive reserve has been demonstrated among other clinical populations, such as dementia, as it has been shown that high levels of pre-morbid neurocognitive ability serve as a buffers against disease-related cognitive decline (e.g. Roe, Xiong, Miller, & Morris,
Among the aims of the current study was to apply the idea of cognitive reserve to adolescent TBI by exploring the relationship between neurocognitive ability and post-intervention behavior.

Authors have suggested that measures of verbal intelligence (e.g. the Vocabulary subtest) reliably assess pre-morbid functioning after neurological insult, such as TBI (Lezak, Howieson, & Loring, 2004). For this reason, the Vocabulary subtest may provide the best evidence for cognitive reserve in the current study. The current study offered limited evidence for cognitive reserve as higher Vocabulary scores were associated with substantially better parent reports of behavior problems at the six-month follow-up regardless of intervention status (CAPS or IRC) for one of four dependent measures. Consistent with what would be predicted given the Cognitive Reserve Hypothesis, the current findings suggested that higher verbal intelligence was protective against the development of post-injury behavior problems. However, as discussed above, verbal intelligence may be closely tied to family environment, making it difficult to distinguish the specific effects of income from verbal intelligence in respect to responsiveness to CAPS.

Who is the best fit for CAPS?

The greatest evidence for the efficacy of the CAPS intervention was found in regard to MI-related behavior problems with no evidence found with for externalizing behaviors, internalizing behaviors, or global functioning deficits. The relationship of meta-cognitive abilities to the CAPS intervention seems reasonable given that the MI-subscale is a measure of the ability to initiate, plan, organize, and sustain future oriented problem solving skills, manage tasks, and monitor performance (Gioia, Isquith, Guy, & Kenworthy, 2000). As a problem-solving intervention, CAPS would be expected to result in improvements in these areas. Therefore, the
CAPS intervention may be a good fit for those experiencing behavior problems that result from meta-cognitive deficits, particularly those with more severe deficits. The interactions identified when considering MI as the dependent variable (group with income and group with vocabulary) suggested that participants with greater long-standing vulnerability, which included lower income status or lower verbal intelligence, benefited most from the intervention. In contrast, higher functioning or individuals of higher socio-economic status seemed to benefit from the non-invasive IRC intervention; this may be because the IRC allowed the family to choose resources based on existing needs rather than having a structured program, such as CAPS.

Finally, factors that are known to be highly affected by TBI, such as processing speed, short-term memory/attention, and injury severity, did not predict response to CAPS. Overall, the current study indicated that consistent, long-standing characteristics, such as income and verbal intelligence, are predictive of response to CAPS while injury related characteristics, such as processing speed, short-term memory/attention, and injury severity, do not predict response to CAPS.

As previously noted, there is a substantial amount of shared variance between income and verbal intelligence. However, it is worth discussing how income and verbal intelligence potentially influence responsiveness to the CAPS intervention. With respect to income, consistent with the theorizing of other authors, we propose that participants from lower income families have greater vulnerability to the effects of TBI as such families are more likely to have unaddressed, pre-morbid behavior problems that may have been related to the lack of resources and greater environmental stress (e.g. Taylor et al., 2002; Spieker, Larson, Lewis, Keller, & Gilchrist, 1999; Catroppa et al., 2008; Boroughs, Massey, & Armstrong, 2005; McLoyd, 1997 as referenced in Bradley & Corwin, 2002). Specific to TBI, it may have been that lower income
families were less likely to be able to dedicate time and/or financial resources to rehabilitation post-injury (Taylor et al., 2002).

For neurocognitive functioning, lower verbal intelligence may reflect an inability to express oneself verbally that corresponds to poorer verbal mediation of metacognitive strategies. That is, those with lower verbal intelligence may have had a more difficult time with verbal expression, which may have resulted in less ability to regulate behavior, organize and structure the environment, and implement effective behavioral solutions. Conversely, higher verbal intelligence may allow for greater ability to inhibit potentially disadvantageous behavioral responses (Ayduk, Rodriguez, Mischel, Shoda, & Wright, 2007). Specific to meta-cognition, higher verbal abilities may mediate problem-solving abilities and coping skills by allowing the individual to better articulate feelings and deficits, negotiate solutions, and implement environmental structure. Higher verbal abilities may also allow the individual to learn compensatory strategies quickly, making external behavioral supports less necessary.

**Internalizing Behaviors**

The only dependent variable for which no significant findings were found was the Internalizing Behaviors subscale. In the current study, baseline internalizing behaviors scores were not clinically elevated at the baseline or six month time points. However, it is not the case that internalizing behaviors are not problematic following TBI as research has shown that internalizing behaviors, specifically symptoms of anxiety, are prevalent (e.g. Max et al., 1998; Levi, Drotar, Yeates, & Taylor, 1999; Wade, Michaud, & Brown, 2006; Grados et al., 2008; Vasa et al., 2002). Instead, it may be that internalizing behaviors, which include symptoms of anxiety and depression, are less apparent to parents/caregivers and that adolescents may be less likely to receive consequences at school and in the community for internalizing behaviors in
comparison to externalizing behaviors, which can include explosive behaviors and being verbally disruptive. As a result, the current findings may represent an under-reporting of internalizing behavior problems. Additionally, there is evidence to suggest that internalizing problems are more likely to resolve than externalizing during the initial year post injury (Bloom et al., 2001); for the current study, it may be the case that internalizing problems may have begun to resolve at the six-month time point, with externalizing problems persisting.

The IRC as a comparison group

While the IRC was used as a comparison group to determine if the CAPS intervention had an effect relative to a demographically-matched group who did not receive the intervention, the IRC group is not a no-treatment or standard care control group, as conceived of in the traditional sense. While the IRC group did not receive the CAPS intervention, the IRC intervention itself, which afforded access to internet resources on brain injury and encouraged families to use these resources on a weekly basis, may have contributed to improvements among IRC participants. There may have also been an effect of being enrolled in a research study which may have motivated the family to seek resources and attempt to implement practices that may have resulted in positive changes within the family. Therefore, the IRC may be better conceived as a self-guided, non-invasive, information-based intervention.

Limitations

While the current study contributed to the currently limited literature regarding neurocognitive predictors of response to post-TBI interventions, there are some key areas of neurocognition that were not assessed. One potentially relevant cognitive domain is executive functions, which is often conceptualized as one’s problem-solving and reasoning abilities (e.g. Blakemore & Choudhury, 2006; Bechara & Van Der Linden, 2005; Buelow, 2009). While the
current study utilized the CVLT, a measure of numerous neurocognitive abilities including executive functions (Pennington, Bennetto, McAleer, & Roberts, 1996), an objective measure of problem-solving abilities was not included.

Difficulties with executive functions, specifically problem-solving deficits, are known to be common post-injury (e.g. Levin & Hanten, 2005; Levin et al., 2001; Yeates, 2002; Somine et al., 2002) and may exert a particularly important influence on long-term functioning following adolescent TBI as executive dysfunction has been associated with increased risk-taking behaviors (Mazaux et al., 1997) and decreased ability to evaluate possible consequences of social behavior (Levin et al., 2005; Leon-Carrion, Garcia-Orza, & Perez-Santamaria, 2004; Bechara & Van Der Linden, 2005). Given the presence of executive functioning deficits post-injury and the relationship to long-term functioning, the assessment of executive abilities may particularly relevant to the study of post-injury interventions. Specific to CAPS, a problem-solving intervention, executive functions would be expected to be related to the ability of the participant to implement and utilize problem-solving skills. Additionally, the use of an objective measure of executive functions task would be expected to be a significant predictor of scores on the BRIEF, which was designed to be a measure of behavioral manifestations of executive dysfunction (Gioia, Isquith, Guy, & Kenworthy, 2000).

Measures of social adaptability and pragmatic judgment may be another skill set that may predict response to post-TBI intervention. For example, the Pragmatic Judgment subtest from the Comprehensive Assessment of Spoken Language (Carrow-Woolford, 2000), a measure of social communication skills, has been shown to be sensitive to the negative effects of TBI (Taylor et al., 2008). Although not specifically identified as a predictor of response to intervention, social communication may be an important component of post-TBI intervention. Impaired social
communication may result in an inability to express oneself in a socially acceptable manner, which can then lead to the development of tendencies to act out behaviorally.

There may also be limitations regarding the nature of the CAPS intervention. One of the primary limitations is the limited number of sessions (maximum of twelve), which may be too few for meaningful behavior changes to be expected to occur. Additionally, the study design makes it difficult to distinguish between improvements that are due to the specific problem-solving aspects of the CAPS intervention from improvements that would be attributable to the involvement with a therapist. Therefore, it is difficult to demonstrate that the nature of the CAPS intervention as a family centered, problem-solving intervention yields better results than other types of interventions that provide a therapeutic relationship.

This study is further limited by a lack of knowledge regarding pre-morbid behavioral and neurocognitive functioning. While some authors have contended that measures of verbal intelligence (e.g. the Vocabulary subtest) are among the most reliable measures available for assessing pre-morbid neurocognitive abilities (Lezak, Howieson, & Loring, 2004), the issue remains that it is difficult to obtain reliable information regarding pre-morbid behavioral functioning. Other studies (e.g. Yeates et al., 2010; Chapman et al., 2010) have relied on retrospective reports on pre-morbid functioning; however, the accuracy of such reports are suspect as it is likely that parents may be biased by current functioning and may be unable to reliably report pre-morbid behavioral functioning, especially as time since injury becomes greater. Related, it may be that reports of behavioral functioning that rely solely on parent reports may be inflated by social desirability biases, therefore reducing reliability.

Issues regarding the representativeness of the sample may limit the generalizability of the findings. Among the issues noted are those related to the heterogeneity of the sample, with the
majority of participants being white males. However, the bias towards males may reflect the TBI population as TBI has been shown to occur more often in males, with some studies indicating that the incidence of TBI is twice as high in males (Kraus & Nourjah, 1988). Lastly, because one of the exclusionary criteria was that English must be the primary language spoken in the household, some participants from diverse populations may have been excluded.

Statistical issues, specifically in respect to the design of the regression models, were present. As stated in the data analysis plan, injury severity (as measured by GCS) and baseline behavior ratings were entered in the first step to control for differences in pre-intervention behavior and severity of TBI. However, in all case, the vast majority of the variance was accounted for in this first step with baseline behavior regularly being a significant predictor of post-intervention behavior. Given that a large proportion of the variance was accounted for in the first step, there may have not been enough remaining variance to fully understand the predictive ability of the socio-demographic and neurocognitive factors above injury severity and baseline behavior. Another statistical issue may exist regarding the number of comparisons made and the number of factors and dependent measures that yielded non-significant findings. Given that the majority of the factors (PSI, Matrix Reasoning, CVLT, caregiver education) and dependent variables (Externalizing Behaviors, Internalizing Behaviors, and CAFAS) yielded non-significant group effects, it can not be definitively determined that the significant results involving income and Vocabulary with MI as the dependent variable were not spurious findings. Therefore, these results need to be replicated to determine if they are spurious or reflective of a true phenomenon.

As previously noted, our exploratory analysis that sought to investigate the influence of adherence to post-intervention behavioral outcomes was limited by the nature of the data used to
approximate adherence. Specifically, the number of sessions completed is a crude estimate of adherence that does not account for a multitude of relevant factors, such as time taken to complete the sessions, no-shows, cancellations, illness, vacations and/or technical difficulties. Due to this limitation, future investigations that seek to assess the role of adherence may wish to account for such factors. Better measures of adherence may include a ratio of the number of sessions completed to the number of sessions scheduled. Measures that assess other factors related to the therapy process, such as motivation to change and therapeutic alliance, may further contribute to our understanding of therapy process factors influence the relationship of socio-demographic and neurocognitive factors to post-intervention behavioral outcomes. Also, the number of sessions completed variable suffered from a limited range as the maximum number of sessions possible was twelve, with the majority of participants completing at least five sessions (see Figure 12). Finally, because the exploratory analysis only included participants in the CAPS group ($n = 66$), it may have suffered from limited statistical power, which could have restricted our ability to detect trends in the data.

*Innovation and contribution to the literature*

Although post-TBI behavioral deficits in children have been widely researched (e.g. Yeates et al., 2010; Chapman et al., 2010; Schwartz et al., 2003; Taylor et al., 2002; Yeates et al., 2010; Vasa et al., 2002; Ganesalingam, Sanson, Anderson, & Yeates, 2007; Ganesalingam, Sanson, Anderson, & Yeates, 2006), little is known about the effect of TBI in adolescence, interventions to alleviate post-injury behavioral and problem-solving deficits, and predictors of responsiveness of post-injury interventions. The current study addressed these issues with the advantage of doing so by utilizing a large sample size ($N = 132$). This study also contributed to the currently limited literature that investigates the effectiveness of internet-based interventions...
as a potentially useful tool for reaching adolescents with TBI and their families that might not otherwise be able to receive post-injury interventions, such as those who live in rural areas. By using the internet to deliver clinically relevant and cost-effective services, this intervention offers more options to researchers and clinicians who seek to find alternate mediums for the delivery of mental health services.

Additionally, the relationship between neurocognitive functioning and responsiveness to interventions has yet to be investigated. This statement not only applies to the TBI literature, but to the broader psychological literature. Given that impaired neurocognitive abilities are related to persistent behavior problems (e.g. Barkley, 1997; Morgan & Lilenfeld, 2000; Baum et al., 2010), research is necessary to examine the effect of neurocognitive deficits on responsiveness to interventions that seek to address behavioral problems. The current study makes a unique contribution by being the first of which we are aware that specifically addressed the relationship of neurocognitive ability to response to intervention after neurological insult.

Finally, the current study is innovative in its approach as the CAPS intervention is tailored to individual based on information collected prior to and during the intervention. Additionally, CAPS is tailored to the needs of the individual while also incorporating the family into the intervention as a means of improving communication and quality of interactions between family members, which has been suggested as an effective approach (e.g. Kumpfer & Alvarado, 2003; Feeney & Ylvisaker, 2003).

Overall, this study provides further information regarding individual factors, including neurocognitive ability, socio-demographic characteristics, and therapy process considerations that predict response to an online problem-solving intervention. Given the results of this study,
clinicians have a greater ability to tailor post-injury interventions to the individual, thus increasing efficacy.
Bibliography


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*Psychological Medicine*, 27, 1337- 1344.


Figure 1. Hypothesized relationship among the factors

Injury severity (GCS) → Group assignment: CAPS or IRC → Baseline behavior: MI, Externalizing, Internalizing, and CAFAS

Neurocognitive factors: PSI, Vocab, Matrix Reasoning, CVLT-2

Socio-demographic factors: income and caregiver education

Behavioral outcomes: MI, Externalizing, Internalizing, and CAFAS

Socio-demographic factors: income and caregiver education
Figure 2. Delineation of participating and non-participating families.

Assessed for eligibility (N = 337)

Not meeting inclusion criteria (n = 49)
Declined to participate (n = 70)
Not able to be contacted (n = 9)
Timed out (n = 77)

Randomized (n = 132)

Allocated to CAPS (n = 66)
Lost to follow-up (n = 0)
Discontinued intervention (chose not to continue to participate once enrolled; n = 3)
Analysed (n = 63)
Excluded from analysis (n = 0)

Allocated to IRC (n = 66)
Lost to follow-up (n = 1)
Discontinued intervention (n = 3)
Analysed (n = 63)
Excluded from analysis (n = 0)
Figure 3. Distribution of CAFAS scores at baseline.

![Figure 3](image1)

Figure 4. Distribution of CAFAS scores at six-month time point.

![Figure 4](image2)
Figure 5. Distribution of the logarithm of CAFAS baseline scores.

Figure 6. Distribution of logarithm of CAFAS scores at six-month time point.
Figure 7. Distribution of unadjusted median income.

Figure 8. Distribution of adjusted median income.
Figure 9. Distribution of baseline MI scores.
Table 1. Means and standard deviations for data collected at baseline.

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* Significant group difference (CAPS or IRC) at 0.05 alpha level.
Table 2. Correlations among baseline variables.

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** Correlation significant at 0.01 level (two-tailed)
* Correlation significant at 0.05 level (two-tailed)
Table 3. Untrimmed regression model examining neurocognitive predictors.

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### Table 4. Untrimmed regression model examining socio-demographic predictors.

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**Note:** Significant at p < .05. **Significant at p < .01.
Table 4. Untrimmed regression model examining socio-demographic predictors (continued).

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Table 5. Trimmed regression model representing the combined effects of socio-demographic and neurocognitive factors.

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Figure 10. Simple slopes analysis for interaction among group and Vocabulary with MI as the dependent variable.

Figure 11. Simple slopes analysis for interaction among group and income with MI as the dependent variable.
Figure 12. Distribution of the number of sessions completed at the six-month time point.