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SOCIAL AND EMOTIONAL BEHAVIOR IN INFANTS AND TODDLERS WITH CHILDHOOD TRAUMATIC BRAIN INJURY

Master's thesis

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Running head: Social-emotional behavior and childhood TBI

Tartu 2008

ABSTRACT

Traumatic brain injury is the most common cause of death and disability in childhood. Our findings suggest that children with TBI exhibit more problematic pre-injury social and emotional behaviors, mainly in self-regulation and autonomy. These difficulties in self-regulation and autonomy were also present post-injury and new problems in interaction with other people had emerged. We also found that there are significant gender differences in both pre- and post-injury social and emotional problems. While boys have more difficulties with self-regulation, compliance and interaction with other people, girls are more prone to have problems in adaptive functions. After TBI the interplay of poorer self-regulation, autonomy and interaction with peers and other people in boys and lower adaptive skills in girls may have serious effect on these boys' and girls' future life. Early gender specific detection and intervention of emerging social-and emotional problems is crucial.

Keywords: social and emotional behavior, development, self-regulation, childhood traumatic brain injury.

KOKKUVÕTE

Lapseea ajutraumaga väikelaste emotsionaalne ja sotsiaalne käitumine

Lapseea ajutrauma on üks sagedasemaid laste suremuse või edasiste tervisehädade põhjusi. Meie uuringu tulemused kinnitavad, et ajutraumaga lastel esineb juba enne traumat eakaaslastest rohkem sotsiaal-emotsionaalseid probleeme: raskusi valmistab nii enesekontroll kui ka iseseisvus ning traumajärgselt lisandusid ka suhtlemisraskused teiste inimestega. Veel leidsime, et nii enne kui ka peale traumat esines poistel rohkem probleeme enesekontrollis, sõnakuulekuses ja teiste inimestega suhtlemises ning tüdrukutel oli raskuski adaptiivsetes võimetes. Kehvem enesekontroll, iseseisvus ning suhtlemisraskused teiste inimestega poistel ja kehvemad adaptiivsed funktsioonid tüdrukutel võivad olulisel määral mõjutada ajutraumaga poiste ja tüdrukute edasist elu. Väga oluline on soo spetsiifiliste sotsiaal-emotsionaalsete probleemide avastamine ning sobiva sekkumisstrateegia rakendamine probleemide varases etapis.

Märksõnad: sotsiaalne ja emotsionaalne käitumine, areng, enesekontroll, lapseea ajutrauma.

INTRODUCTION

Traumatic brain injury (TBI), also referred to as closed-head injury, is a form of acquired brain injury that arises as a result of blunt trauma to the head (Yeates, 2000). TBI is the most common cause of death and disability in young people (Ghajar, 2000) with a mortality rate of 10 per 100,000 children (Langlois, Rutland-Brown, & Wald, 2006). This mortality rate alone, although concerning, does not fully describe the impact of TBI.
In the United States, among the entire pediatric population of age 0-14 years, the average incidence of all types of TBI has been reported to be 475 000 a year (Langlois *et al.*, 2006). According to the epidemiological study of Ventsel, Kolk, Talvik, Väli, Vaikmaa & Talvik, (2008), the incidence of TBI in childhood in Estonia is up to 369 out of 100 000.

Most studies report incidences based on contacts with the health care system and give figures for mild TBI to 80-90% of the total incidence, moderate TBI to 7-8% of the total incidence, and severe TBI to 5-8% of the total incidence (Langlois *et al.*, 2006; Bruns & Hauser, 2003; Hawley, Ward, Magnay, & Long, 2003; Cassidy, Carroll, Peloso, Borg, von Holst, Holm, Kraus, & Coronado, 2004). About 82% of TBI cases in Estonia were evaluated as mild (303 per 100 000), while moderate and severe TBI-s constituted 18% of the cases. TBI was fatal in 0.8% of the cases (Ventsel *at al*., 2008).

It is estimated that in any one year, as much as 70 out of 100 000 children are hospitalized because of TBI (Schneier, Shields, Hostetler, Xiang, & Smith, 2006). In Tartu University Hospital’s Children’s Clinic about 13% out of all patients hospitalized in the department of Neurology and Neurorehabilitation are victims of TBI. Of all pediatric head trauma hospitalizations in the United States, 11.6% are infants below the age of 1 year (Schneier *et al*., 2006). TBI represents a major public health problem and reflects an ongoing social and economic burden for the community. In 1990, TBI was added as an educational disability category for special education in the Individuals with Disabilities Education Act.

TRAUMATIC BRAIN INJURY

Mechanism of traumatic brain injury

The cascades of events during the brain injury are not completely understood and have been separated into primary and secondary injuries (Mendelow, Teasdale, & Jennet, 1990). Primary injury is the physical deformation of skull, brain, and blood vessels at the time of impact. The injury may result from external objects striking or penetrating the head, sudden acceleration, deceleration or torsion. The conditions may occur alone or in combination. Acceleration and deceleration typically occur in motor vehicle accidents. Violent shaking may exert rotational forces (e.g. shaken-baby syndrome). Impact of the brain against the interior of the cranium may cause laceration, contusion, and bleeding.

Primary processes are best conceptualized in two categories: focal injuries and diffuse injuries. Focal injuries are confined to one area of the brain, whereas diffuse injuries involve more than one area of the brain.

Focal injuries are caused by shearing of dural and vascular attachment to the inner surface. Types of focal brain injuries include bruising of brain tissues – contusions, intracranial hemorrhages, hematomas. Contusions characteristically occur at the crest of gyri. Early stage contusions are characterized by punctate hemorrhages, which later become more extensive with blood flow permeating into white matter. Eventually these acute contusions are represented by shrunken, often brown scars. Regardless of the site of the original injury, contusions particularly tend to affect frontal poles, orbital surfaces of frontal lobes, temporal lobes and the cortex above and below the Sylvian fissure (Gannarelli & Graham, 1998). Ventral and polar frontal and temporal regions are particularly prone to contusional damage because these areas involve excessive tissue strains against the ridges and confines of the anterior and middle fossa (Gentry, Thompson, & Godersky, 1988). There are numerous subdivisions of contusions including contusions that occur directly beneath fractures, coup contusions that occur under the site of impact, contercoup contusions that occur in regions distant to (but not always opposite of) the impact site, herniation contusions, and gliding contusions, the latter being associated with diffuse injuries. There are also several categories of hemorrhage including intracranial hematoma associated with a direct rupture of a blood vessel, extradural hematoma associated with skull fracture, and acute subdural hematoma caused by a rupture of the bridging veins of the dura or possibly cortical arteries. Hemorrhages may usually involve subcortical white and gray matter (e.g. caudate, dorsomedial, and ventral anterior thalamus), or structures involved in fronatal-subcortical circuits (Cummings, 1993). Scalp hematoma may conceal a skull fracture and, in infants, can result in significant blood loss. Simple linear fractures are generally benign, but the presence of any fracture greatly increases the risk for intracranial hemorrhages. Skull fractures are reported after 20% of childhood traumatic brain injuries (Harwood-Nash, Hendrick, Hudson, 1971), but especially among children up to 40% of the epidural hematoma cases occur without skull fracture (Stalhammer, 1990).

Head trauma is by its nature a diffuse process and bilateral swelling can occur in the absence of discrete focal lesion. In fact, diffuse brain injury is more common in children, because of the greater head-to-torso ratio and brain-water content, whereas focal cerebral damage like contusion is more common in older adolescents and adults (Lang & Chesnut, 1994; Mazzola & Adelson, 2002). Diffuse injuries are generally associated with concussion (discussed later in detail *) diffuse axonal injury or coma. Diffuse axonal injury, the second most common form of diffuse injury after concussion, results from acceleration/deceleration forces leading to disruption of axonal degeneration. As a consequence, there is a widespread, scattered deafferentation of axonal projections, including those involving prefrontal system. By its nature, diffuse axonal injury can occur throughout the brain, with the propensity for regions with major fiber tract (e.g. corona radiate, corpus callosum, and brainstem).

Secondary injury occurs minutes, hours, or days after the insult and is manifested by progression of cerebral edema, elevation of intracranial pressure, continued fall of cerebral blood flow, and ongoing cytotoxic neural damage (Helfaer & Wilson, 1993). Secondary response to injury is complex, and involves a system of cascades with positive and negative feedback (Kennedy & Moffat, 2004). It involves many physiologic, biochemical, and inflammatory changes that occur after the primary injury and can adversely affect vulnerable neurons unaffected from the primary injury. The complex cascades of secondary injury involve inflammatory cells and mediators, excitatory neurotransmitters, transmembrane movement of calcium and other electrolytes, lipid peroxidation, oxygen free radicals, apoptosis, nitric oxide production, and a myriad of other reactions, and can potentially lead to progressively worsening swelling and neuronal death (Kochaneck, 2006). Secondary injury contributes a large amount of morbidity and mortality from TBI (Sullivan, 2000).

Mild, moderate and severe TBI

In addition to dividing TBI into diffuse and focal brain injury, it is possible to further separate TBI depending on the extent of the damage to the brain. One can hereby distinguish mild, moderate and severe TBI.

Severity of TBI may be defined in terms of injury characteristics, level of consciousness or the severity of computed tomography (CT) magnetic resonance imaging (MRI) appearances. The level of consciousness at presentation, measured using the Glasgow Coma Scale (GCS), is predictive of neurological outcome (Teasdale & Jennet, 1974). GCS has three components: eye opening (ranging from 1 to 4), best verbal response (ranging from 1 to 6) and best motor response (ranging from 1 to 6), for a total score from 3 (worst) to 15 (normal). Special modifications of GCS are available for evaluating pediatric population, especially young children and infants (Reilly, Simpson, Sprod, & Thomas, 1988).

According to Rosman, Herskowitz, Carter, & Connor (1979), mild head injury results in GCS score of 13 or higher in the acute period, as well as clinical symptoms of disorientation, altered mental status, and headache or vomiting. Concussion is by far the most commonly diagnosed subtype of mild head injury. It is characterized by transient loss of consciousness with loss of awareness immediately following a head injury. The loss of consciousness (<30 minutes) is attributed to an increase in intracerebral pressure, followed by a shear strain on the upper brain stem (Rosman *et al.*, 1979). According to other criteria TBI is considered mild if GCS is 15; there is a loss of consciousness up to 5 minutes, or vomiting up to three times, and no neurological location. Mild TBI is considered a benign and trivial neurological condition that results in an apparently uneventful recovery. However, a minority of mild TBI patients experience continuing post-concussional complaints like subtle memory deficit and concentration weakness, fatigue, dizziness, anxiety and depressive symptoms, suggesting chronic brain damage (Alexander, 1995; Yang, Butterworth, Griffiths, Hansen, Preston, Ritch, & Rivers, 2007).

Moderate head injury is usually defined by an initial GCS score of 9 to 12, a loss of consciousness for between 15 minutes and 6 hours, and a period of post-traumatic amnesia of up to 24 hours. The above are not the only criteria to diagnose a moderate TBI as according criteria widely used in clinical practice moderate TBI is diagnosed in patients with a GCS score of 11-14, or loss of consciousness for more than 5 minutes, vomiting more than three times, dizziness and headaches, seizures after trauma, posttraumatic amnesia, multiple traumas, fracture of skull and facial bones, and child abuse. Like those with mild TBI-s, patients with moderate TBI-s are likely to suffer from a number of residual symptoms. Most commonly reported symptoms include tiredness, headaches and dizziness (physical effects), difficulties in thinking, attention, memory, planning, organizing, concentration and word-finding problems (cognitive effects) and irritability (an emotional and behavioral effects). Patients with moderate TBI-s pose a case management challenge. This group represents a heterogeneous population with significant variability in terms of trauma severity, hospital course, neurological recovery, and sequelae (Vitaz & Jenks, 2003).

Patients with severe TBI have a GCS score of 8 or less and have been in a coma for 6 hours or more, or have had a post-traumatic amnesia of 24 hours or more. In clinical practice following criteria for severe TBI diagnosis is also used: GCS score 10 or less or a neurological location. Depending on the length of time in coma, severe TBI patients tend to have serious physical deficits. Most patients with severe TBI, if they recover consciousness, suffer from cognitive disabilities.

Main causes of traumatic brain injury

Demographic risk factors for all childhood injuries include poverty, single-family households, and congested living conditions. Psychiatric histories, drug and/or alcohol use, and physical illness are found more frequently among the parents of injured children. Unsupervised play is also reported more frequently, which may be directly related to incidence of injury (Chadwick, Rutter, Brown, Shaffer, & Traub, 1981). Child behavioral characteristics associated with high traumatic brain injury rates include impulsivity, aggression, and attention seeking behavior. These characteristics might also be seen as causes of injury (Matheny, 1987). A previous history of traumatic brain injury is also associated with an increased risk of further traumatic brain injury in children (Annegers, 1983). Multiple TBI-s are strongly related to socioeconomic factors and behavioral characteristics such as hyperactivity and aggression (Bijur & Haslum, 1995).

Retrospective studies have revealed that main causes of childhood TBI are traffic and motor vehicles related (42%) in most of the cases. On average, traffic accidents and falls are reported to account for 75-80% of all brain injuries, whereas the proportion of traffic accidents varies greatly from 19% reported in Iceland to 77% reported in Northern England. Falls are reported to be the cause of TBI in 13-62% of the cases, with the highest incidence rate being reported in Iceland (Arnarsson & Haldorsson, 1995). In Estonia falling is the main cause of childhood TBI in all age groups (63% of the cases) (Ventsel *et al*, 2008). Worldwide, sports and leisure activities are reported to be the external cause in 1-20% of the pediatric TBI cases, but there is a wide geographical and seasonal variation. For example, accidents in skateboard skating and roller-skating in Denmark in 1988 were estimated to have an annual incidence of 16 out of 100 000 concussions among children of age up to 14 (Engeberg, 1995; Engeberg & Teasdale, 1998).

The peak incidence of childhood TBI occurs during adolescence and young adult years, with a secondary peak in infancy (Kraus & McArthur, 2000). The etiology of TBI varies with age. Schoolchildren up to 14 years of age are prone to suffer traffic accidents and adolescents are more frequently involved in high speed motor vehicle accidents, but mainly sustain childhood TBI because of a fall, while riding a bike or as a pedestrian (Thurman & Guerrero, 1999). In Estonia, cycling and road accidents are the second most common causes of TBI among children 4-15 years of age and contribute 19.6% of all TBI-s (Ventsel *et al.*, 2008).

For infants and toddlers, falls are the causes of 20-70% of TBI cases (Thurman & Guerrero, 1999). Infants are also vulnerable to repeated severe traumatic brain injury (2-10%) in a form of nonaccidental trauma – inflicted traumatic brain injury (Barlow & Minnis, 2000). Recent childhood TBI studies in Estonia reveal a similar trend: falls are the main causes for TBI among children of up to 4 years of age (79%). In addition, 5% of infants and toddlers diagnosed with TBI are dropped by parents or by siblings. For children over 1 year, assaults cause TBI in 3.8% of the cases (18 cases). Of those cases, 44.5% are caused by aggressive behavior of other children, while in 55.5% of assaults are caused by adults (Ventsel *et al.*, 2008). Child abuse rate in the USA among children under age of 5 is ranging from 2.9 out of 100 000 in Connecticut to 15.4 out of 100 000 in Nevada (McClain, Sachs, Ewingman, Smith, Mercy & Sniezek, 1994). In a four-year hospital-based study from Malaysia on cases of proven child abuse (Cheah, Kasim, Shafie & Khoo, 1994) almost 90% of the children were younger than 2 years. In 95% of the cases child abuse caused serious intracranial hemorrhage.

In Estonia in Tartu County during the period 2001-2004 inflicted traumatic brain injury or shaken-baby syndrome was diagnosed in 4 cases in children under the age of 4 years (Ventsel *et al.*, 2008). Talvik, Metsvaht, Leito, Põder, Kool, Väli, Lintrop, Kolk, & Talvik, (2006) have previously pointed out that Estonia has a high frequency of shaken-baby syndrome – 40.5 out of 100 000 children under age 1 year, compared to 24.6/100 000 reported in Scotland by Barlow& Minnis (2000).

The causes of TBI in Estonia do not differ much from the causes of TBI reported in USA and Western-Europe, The abundant childhood TBI incidences in Estonia compared to USA and Western-Europe could be partly explained through different methodological approaches used to evaluate the incidences of TBI in different countries. However, the main point of concern is that the incidence rate in Estonia is especially high among infants and toddlers from 0 to 4 years of age – 566 out of 100 000 (572 out 100 000 for boys and 559 out of 100 000 for girls) (Ventsel *et al.*, 2008).

Brain injury in immature brain.

Empirical (Kolb & Tomie 1988; Villablanca & Hovda, 1999) and clinical (Trauner, Chase, Walker, & Wulfeck, 1993) evidence is available to support the position that the developing brain has remarkable resilience to focal injuries such as strokes or surgical resection, but its ability to recover from diffuse injuries may be much more limited (Levin, Benavidez, Verger-Maestre, Perachio, Song, Mendelsohn, & Fletcher, 2000). Studies of developmental plasticity in children with TBI suggest that pediatric TBI results in altered brain development. Levin (1992) found that children who sustained their injury in infancy had poorer outcome than children injured later in life. The early vulnerability hypothesis is supported by the case study by Marin-Padilla, Parisi, Armstrong, Sargent & Kapalan (2002), who found that a child who sustained neonatal head injury exhibited abnormal cortical development. In animal studies similar findings have been reported by Bittigau, Sifringer & Pohl (1999) who argued that the benefits of youth are even less evident when the injury occurs in a critical window of brain development.

In general, existing evidence does not support the notion that young brain is less vulnerable to damage or recovers better than mature brain. Instead, existing evidence suggests a „double-hazard" model for severe and early brain damages and adds to the ongoing debate regarding cerebral plasticity, suggesting that contrary to traditional views, young children who sustain severe TBI in early childhood, or moderate or sever TBI in infancy may be particularly vulnerable to significant residual impairment (Anderson & Catroppa, 2005). It is not yet conclusively clear, however, whether this is true for all ages, etiologies, or severity levels of traumatic injuries.

Cognitive sequela after TBI

TBI in childhood is a serious health problem not only due to the high mortality rate but also because of several long-term neurological disabilities (epilepsy, headache, movement disorder) as well as behavioral and cognitive problems (Anderson, Morse, Catroppa, Haritou & Rosenfeld 2004; Catroppa & Anderson, 2005; Anderson & Catroppa, 2006; Gil, 2003). Researchers agree that these problems tend to exist after severe TBI (Anderson *et al.*, 2004), but there is evidence which suggests that even mild TBI can cause various neurological and cognitive problems (McKinelay, Dalrymple-Alford, Horwood, & Fergusson, 2002).

A number of studies which have investigated the nature of neuropsychological impairment following childhood TBI in school-aged children and adolescents, suggest that, even years after injury, deficits are evident in attentional capacity (Catroppa & Anderson, 1999; Fenwick & Anderson, 1999; Arciniegas, Adler, Topkoff, Cawthra, Filley & Reite, 1999), memory and learning (Levin, High, Ewing-Cobbs, Fletcher, Eisenberg & Miner, 1988, Anderson, Catroppa, Rosenfeld, Haritou & Morse, 2000, Catroppa & Anderson, 2002, Serra-Grabulosa, Salgado-Pineda, Junque, Solé-Padullés, Moral, López-Alomar, López-Guillén, Bargalló, Mercader, Clemente, & Bartrés-Faz, 2005) psychomotor skills (Bawden, Knights, & Winogron, 1985), linguistic abilities (Ewing-Cobbs, Miner, Fletcher, & Levin, 1989; Catroppa & Anderson, 2004) and executive functions (Dennis, Barnes, Donnelly, Wilkson, & Humphreys, 1996; Levin, Scheibel, Fletcher, Harward, & Lily, 1997, for review see Levin & Hanten, 2005). Recent studies of preschool children with traumatic brain injuries indicate that injuries sustained during infancy or early childhood are associated with more persistent cognitive deficits than are brain insults occurring during later childhood and adolescence (Anderson *et al*., 2005; Anderson *et al.,* 2000; Dennis & Barnes, 2000; Donders & Warschausky, 2007).

SOCIAL AND EMOTIONAL BEHAVIOR AND CHILDHOOD BRAIN INJURY

Neurobiology of emotional behavior

According to evolutionary psychology, biologically based emotions represent efficient modes of adaptation to changing environmental demands (Tooby & Cosmides, 1990). Emotions have emerged in the course of evolution by virtue of their capacity to adequately co-ordinate the cognitive, subjective, physiological, and behavioral systems that characterize emotion's multidimensional nature (Levenson., 1994).

In his review Phillips, Drevets, Rauch & Lane (2003) concluded that emotional behavior is dependent upon two neural systems: ventral and dorsal system. The ventral system includes amygdala, insula, ventral striatum, and ventral regions of the anterior cingulate gyrus and prefrontal cortex. The dorsal system includes hippocampus and dorsal regions of the anterior cingulate gyrus and prefrontal cortex, i.e. the regions where cognitive processes are integrated and can be biased by emotional input. The extent to which stimuli are identified as emotive and associated with the production of affective state and/or emotional behavior may depend on levels of activity within the ventral and dorsal system. The ventral system is important for the rapid appraisal of emotional material, production of affective state, and autonomic response regulation, whereas the dorsal system is important for effortful regulation of resulting affective states, performance of executive functions, including selective attention and planning. Specific abnormalities in the functioning of either or both these two neural systems may therefore be associated with abnormalities in emotional behavior and self-regulation (Mega, Cummings, Salloway, & Malloy, 1997).

Stuss (1992) has further proposed that the capacity of emotional self-regulation is crucial executive function that develops in close relationship with the development of the prefrontal cortex. This hypothesis is also supported by some empirical data from MRI studies of structural and functional changes in the developing human brain during the first few decades of life (Casey, Giedd, & Thomas, 2000). With regard to this question, it is noteworthy that myelination and dendritic development occur later in the human prefrontal cortex than in other cortical regions.

Social and emotional behavior and development in with childhood brain injury

While the cognitive and behavioral sequelae of childhood TBI are quite well documented, there are still too few studies focusing on social and emotional consequences of childhood TBI. Some evidence suggests that children with TBI are vulnerable to poor social outcomes (Janusz, Kirkwood, Yeates & Taylor, 2002; Schwartz, Taylor, Drotar, Yeates, Wade and Stancin, 2003; Yates *et al.,* 2004; Ganesalingam, Sanson, Anderson, & Yeates, 2007; Ganesalingam, Yeates, Ginn, Taylor, Dietrich, Nuss, & Wright, 2008). The social and emotional outcome of TBI in infancy and toddlerhood remains largely uncharacterized and poorly understood as we still know little about the nature, basis and consequences of social and emotional problems among preschool children with TBI.

One of the leading studies in the field of investigating the impact of early life brain injury on social and emotional behavior was a case study by Anderson *et al.* (1999). The study covers two patients who had sustained their injury to prefrontal cortices very early in life. The patients were examined 20 years after the brain injury. One of the patients had suffered TBI at the age of 15 months while the other had undergone a resection of right frontal tumor at the age of three months. The case studies revealed that similarly to patients who had sustained their injuries to prefrontal cortices in adulthood, the two early onset patients had severely impaired social behavior despite normal basic cognitive abilities, and showed insensitivity to future consequences of decisions, defective autonomic responses to punishment contingencies and failure to respond to behavioral interventions. But unlike adult-onset patients, early-onset patients also had defective social and moral reasoning, suggesting that acquisition of complex social conventions and moral rules had been impaired. This finding has been hypothesized to reflect the different consequences of damage to wellestablished rule-guided behaviors in adults as compared to the disruption of developing socialization processes in children.

William & Maater (1999) reached somewhat similar findings in an older sample while studying two patients who suffered TBI and had sustained their diffuse frontal lobe injuries at the age of 8 and 11 years, respectively. The authors concluded that the areas most affected by TBI were associated with social and emotional behavior. Not only did the patients demonstrate behavioral regression following their injuries (tantrum behavior, increased dependency), but they also showed abnormal development of social skills and compromise of behavioral/emotional restraints as they grew older. William & Maarter (1992) propose that late emerging deficit patterns may be expected (the so-called "sleeper-effect" or "growing-in to lesion"), reflecting interactions between deficits and failure of development of age-appropriate competences, consequent lack of acquired fundamental skills, new situational demands and emotional responses to failure.

The effect of trauma severity to future social and emotional development has been shown by Fletcher, Levin, Lachar, Kusnerik, Harward, Mendelsohn, & Lilly (1989). Severe head injuries among children were associated with declines in adaptive functioning, whereas results for children with mild and moderate injuries did not show significant difference or deviated from average levels at any follow-up interval. The worse outcome for children with severe TBI in social problem solving and social competence has been shown to persist over time (Janusz *et al.*, 2002, Yeates, Swift, Taylor, Wade, Drotar, Stancin, & Minich, 2004). Somewhat controversial findings have been reported by Ganesalingam, Sanson, Anderson, & Yeates (2006) who studied the self-regulation and social and behavioral functioning in 6-11 year children with moderate and severe TBI. No significant differences were found while comparing moderate and severe TBI groups, but compared to healthy controls children with moderate and severe TBI demonstrated poorer social and behavioral functioning. According to their parents' and teachers' reports, children with TBI engaged more often in "externalizing" behaviors, including defiance, temper tantrums, destructiveness, and restlessness. Furthermore, children with TBI were reported to have difficulties in initiating friendships with peers, giving compliments, requesting help, and helping family members and peers. They were more impulsive, easily distracted and less attentive in cognitive measures. Children with TBI were also reported to have poorer emotions regulation ability: that is their parents described them as displaying less emotional awareness, empathy and situationally appropriate affect. Children with TBI exhibited more often poorly regulated negative affect, including mood swings, flat affect and socially inappropriate emotional expressions

(Ganesalingam, *et al.*, 2006; Ganesalingam *et al.*, 2007). Family's lower socioeconomic status (SES), fewer family resources and poorer family functioning exacerbate negative social outcome significantly (Yeates *et al.,* 2004; Schwartz *et al.,* 2003).

Tonks, Williams, Frampton, Yates, & Slater (2007) showed that childhood brain injury had negative effect on emotion-recognition skills and injured children performed relatively poorer in all emotion-recognition tasks. In accordance with previous findings (Anderson *et al.*, 1999), Tonks *et al.* (2007) found that injured children revealed very few relationships between cognitive functioning and emotion processing measures. This suggests that even when the cognitive abilities are intact the emotion processing may still be severely impaired.

Max, Levin, Schachter, Landis, Saunders, Ewing-Cobbs, Chapman, & Dennis (2006) studied personality changes due to TBI among 5-14 year olds were 6 and 24 months after the injury, and concluded that personality change occurs in 13% of the participants between 6-12 months after injury and in 12% in second year after the injury. Severity of the injury predicts personality change whereas pre-injury adaptive functioning predicts personality change only in the second year after the injury. Lesions of the superior frontal gyrus are associated with personality change between 6-12 months following injury and lesions only in the frontal lobe white matter are significantly related to personality change in the second-year after the injury. This finding confirms the importance of dorsal prefrontal cortex and frontal lobe white matter in effortful and conscious regulation of affective states (Max *et al.*, 2006).

Several studies suggest that children suffering from traumatic brain injury are more likely to have a prior history of behavioral and emotional disorder (Bijur & Haslum, 1995). Goldstrohm & Arffa (2005) even found that premorbid behavioral factors account for most of the problems recognized in post-acute period as well. They reported that no significant worsening of emotional and social behavior was seen in 6 months, but higher rates of family stress and life event changes were reported by parents of children with TBI and orthopedic injury than by parents of non-injured children, suggesting that increase in family stress is not particularly specific to TBI. It is likely that pre-existing cognitive, emotional and behavioral problems affect incidence of injury due to the child's inability to evaluate risks and dangers. Therefore poor social cognition, impulsivity, anxiety, aggression, disobedience and other problematic behaviors in infancy and toddlerhood could be one of the risk factors for later TBI.

Such controversial findings suggest further research about social and emotional behavior and development among infants and preschoolers with TBI. New insights promise to improve our understanding of the developmental variability of TBI throughout childhood, and perhaps expand our knowledge of the complex interplay between age, severity and mechanism of injury in childhood TBI. Due to "sleeper-effect", it is especially important to continue to study the effect of TBI in children longitudinally.

ASQ: SE as one of the instruments suitable to evaluate infants and toddlers social and emotional development

The early identification of social and emotional problems in infants, toddlers and young children is critical for improving developmental outcomes. Prior, Bavin, Cini, Reilly, Bretherton, Wake, & Eadie (2008) studied the temperament and behavioral problems longitudinally within 2 years period in 8 months old healthy infants. And they found that girls were in advance compared to boys in most developmental measures including social and emotional behavior. Mesman, Bonger, & Koot (2001) found that parental ratings for higher levels of over activity and aggression at age 2-3 years were strong predictors to teacher-reported externalizing problems at age 10-11.

Few strategies exist for early and timely identification of young children who have or may develop behavioral or mental health difficulties. One of the possibilities to identify social and emotional problems in children from 3 months to 5 years 5 months is Ages and Stages Questionnaires: Social-Emotional (ASQ: SE) screening tool.

The conceptual underpinning for the ASQ: SE includes the social learning model which posits that social learning occurs as a function of child’s daily social interaction. In addition, the developmental organizational theory and the marginal deviation model provide useful complements to the social learning theory. These theories suggest that the deviation from normal developmental trajectories occurs when the important social, emotional, cognitive, and social-cognitive processes are not meaningfully integrated into more advanced levels of complex functioning. Disturbance at earlier levels will likely cause continuing and more serious disturbances at subsequent levels (for details, Squires, Bricker, & Twombly, 2003).

The ASQ: SE was developed after an extensive review of the literature on social-emotional development, social-emotional and behavioral assessment, and developmental psychopathology. Approximately 40 experts in diverse disciplines including special education, early childhood education, school psychology, communication disorders and science, psychiatry, pediatrics, and child welfare as well as parents reviewed the content of the ASQ: SE and suggested revision and additions. In final United Sates version the psychometric data of the ASQ: SE was as follows: Cronbach's coefficient α ranged from 0.67 to 0.91, indicating strong relationship between questionnaires total score and individual items. Test-retest reliability was reported to be 94%, concurrent validity ranged from 81% to 95%, with overall agreement of 93%. Sensitivity, or the ability of screening tool to identify those children with social-emotional disabilities, ranged from 71% to 85% with 78% overall sensitivity. Specificity, or the ability of a screening tool to correctly identify those children without social-emotional delays, ranged from 90% to 98% with 95% overall specificity. The utility of the ASQ: SE reported by parents (N=731) was 97% (Squires, Bricker, Heo, & Twombly, 2001).

THE AIMS OF THIS STUDY

On the basis of previous studies it is expected that children with TBI show impairment in social and emotional behavior already before the injury and problems in emotional and social behavior tend to persist and even enhance after the injury.

In line with the early vulnerability hypothesis it is expected that children who sustain their injuries in infancy or early childhood are more likely to develop higher scale socioemotional problems. Compared to mild and moderate TBI, severe TBI is expected to result the worst outcome in social and emotional behavior. In accordance with previous findings, parents' education is expected to have an important effect on initial social-emotional outcome, in favor of children with higher-educated parents. Children whose injuries affect frontal areas are expected to do worse in second evaluation compared to children whose injuries do not involve the areas mentioned. Slightly more problematic social-emotional behaviors will be expected from boys than from girls before the injury and in follow-up.

The aims of the present study are:

1) to investigate the social and emotional behavior before the accident in children with TBI;
2) to investigate the pre-injury gender differences in social and emotional behavior;
3) to investigate the associations of pre-injury social and emotional behavior with sex and parents' education;
4) to investigate differences in post-injury social and emotional behavior and post-injury social and emotional development 9 months after the injury during prospective study;

5) to investigate the gender differences of changes in social and emotional behavior 9 months after injury during prospective study;
6) to investigate the associations between trauma severity and changes in social and emotional behavior.

METHOD

The study was carried out from December 1st 2005 to April 1st 2008 at the Tartu University Hospital's Children's Clinic in the Department of Neurology and Neurorehabilitation and consisted of two parts, referred to as Study I and Study II. The study was approved by the Medical Research Ethics Committee of Tartu University and written informed consent was obtained from patients' parents for participation in the study.

Subjects

Study I included 37 children with TBI. The following inclusion criteria were used for patient selection: (1) hospitalization in Tartu University Hospital's Children' s Clinic with diagnosis of TBI; (2) age between 3 to 65 months at the time of the injury; (3) parent's consent to participate in TBI research; (4) parental fluency in Estonian language. The age span at the trauma ranged from 3 to 65 months with a mean age of 33.22 months (SD=19.92). There were 23 boys (mean age 35.43 months, SD=19.70) and 14 girls (mean age 29.57 months, SD=20.47). TBI diagnosis was formulated according to the ICD codes S00-S09, which include all injuries to head (Ministry of Social Affairs, 1995). The severity of TBI was classified according to criteria discussed above. The same classification was previously used in Tartu University Hospital's Children's Clinic in epidemiological study of TBI in Tartu and Tartu county by Ventsel *et al.* (2008).

The causes of TBI were classified according to ICD codes (Ministry o Social Affairs, 1995). The control group was composed of 74 controls matched to age, sex and parents' education. Mean age for control children was 32.85 months (SD=20.05) and none of them had any known neurological or psychiatric diagnosis. Parents' education measures were categorized as follows: (1) both parents have primary education or only data about one parent with primary education is available; (2) one parent has primary education and one secondary education; (3) both parents have secondary education or only the data about one parent with secondary education is available; (4) one parent has secondary education and other parent has higher education; (5) both parents have higher education or only the data about one parent with higher education is available.

In Study II, prospective study, 19 children with TBI (8 females and 11 males) were reevaluated with ASQ: SE age appropriate questionnaire after a mean interval of 9.37 months (SD=3.89).

Measures

We used the questionnaire "Ages and Stages: Social-Emotional Questionnaires" to examine social and emotional behavior in children before and 10 months after TBI. The ASQ: SE is translated to Estonian with publisher consent by the author of the present thesis and is used to evaluate children's social and emotional behavior in Estonia the first time.

"The Ages and Stages Questionnaires: Social-Emotional" (ASQ: SE) is a parent-completed, child-monitoring system for social-emotional behaviors for children in the age of 3 to 6 months, worked out by Squires *et al.* (2001). ASQ: SE consists of a series of questionnaires designed for child's parents or other primary caregivers. The ASQ: SE focuses on child's social and emotional behaviors in the areas of self-regulation, compliance, communication, adaptive behaviors, autonomy, affect and interaction with other people (see Table 1).

Table 1. The ASQ: SE seven behavioral areas and associated definitions.

Behavioral area	Associated definition
Self-regulation	Items address the child's ability or willingness to calm or settle down or adjust to physiological environmental conditions or stimulations
Compliance	Items address the child's ability or willingness to conform to the directions of others and follow rules.
Communication	Items address the child's ability or willingness to respond to or initiate verbal or nonverbal signals to indicate feelings, affective, or internal states.
Adaptive functioning	Items address the child's success or ability to cope with physiological needs e.g. sleeping, eating, elimination, safety).
Autonomy	Items address the child's ability or willingness to self-initiate or respond without guidance i.e. moving to independence)
Affect	Items address the child's ability and willingness to demonstrate his or her own feelings and empathy for others
Interaction	Items address the child's ability or willingness to respond to or initiate social response to parents, other adults, and peers.

Questionnaires span the 3 to 63 months period with assessment intervals at 6, 12, 18, 24, 30, 36, 48, and 60 months. The number of questions per questionnaire ranges from 19 on the 6-month interval to 33 questions on the 48 and 60 months intervals, and are written at 5th to 6th grade reading level. Parents' responses are given point value of 0, 5 and 10. Scores for each item are combined into total score; a high total score is indicative of problems while low score suggests the child's social and emotional behavior is considered within expectations for age (Squires, Bricker, Heo, & Twombly, 2001).

The ASQ: SE has been devised to provide „clinical cut-off" scores for all the age groups. However, rather than using clinical cut-offs, this study compares control group scores to total scores, sub-scale scores, and answers to single-items.

Procedure

In Study I, the parents of children hospitalized with TBI filled the ASQ: SE age appropriate questionnaire to describe their child's behavior within the previous two weeks. Medical records of every TBI patient were re-examined to assure the diagnosis of TBI. The ICD codes in discharge files were registered by the treating physician. Information about parents' education and the cause of the injury was collected while interviewing the parents and later confirmed from the child's medical records. Data of lesion localization and severity was obtained from imaging either by CT or MRI scans. Neuroimages were not available for one child of the group.

A further aim was to observe the changes in social-emotional behavior in our subjects. Therefore in Study II 19 children and age, sex and parents' education matched controls were reevaluated with the same instrument after a mean inter-evaluation interval of 9.36 months (SD=3.89).

From those children in TBI group for whom reevaluation data was unavailable, 9 children were unresponsive to contacting, 5 were out of the questionnaire's age range, and too little time had passed from the initial evaluation of 4 children. At least 6 months was required before reevaluation.

Statistical analysis

The internal consistency of the Estonian translation of ASQ: SE Questionnaires was measured using Cronbach's α method. The raw scores of ASQ: SE subtests were standardized into z-scores to make the scales comparable. The distribution of all subtest scores and single item-scores was evaluated. ASQ: SE questionnaires' subscale scores exhibited non-normal distribution. For consistency non-parametric procedures were used throughout the analysis. Non-parametrical methods have been shown a greater power in distinguishing between very small samples (Bridge & Sawilowski, 1999; Vickers, 2005).

The non-parametric Mann-Whitney *U*-test was used to compare social-emotional behavior between two different groups. When children were divided into more than two groups, the Kruskal-Wallis test was used. Spearman's rank correlation analysis was performed to compare the correlation between trauma severity and ASQ: SE total scores, and between trauma severity and ASQ: SE subtest scores.

For assessing the long-term effects, we used the Wilcoxon matched pairs test to determine the change within groups. To assess the effect of change between TBI and control group score difference was computed by subtracting the subtest scores of second evaluation from the corresponding scores of first evaluation. This score difference was assessed with the Mann-Whitney *U*-test. The correlation with trauma severity and score differences was computed using Spearman's rho measure. Kruskal-Wallis test was used to assess the outcome in TBI children with different parental education. All tests were two-tailed. The significance level was set to α=0.05. Statistical data analysis was performed with *Statistical Package for Social Sciences (SPSS.14)* and *Statistica 6.0* programs.

RESULTS

Internal consistency of ASQ: SE

ASQ: SE questionnaires' internal consistency reliability was evaluated using Cronbach's α coefficient. Similarly to original questionnaires the internal reliability was better in 60 months and 48 months questionnaires (α=0.723, α=0.763 respectively). Moderate internal reliability was seen in 36 months, 30 months, 24 months, (α>0.65), whereas slightly lower internal reliability was in 12 months and 6 months questionnaires (α>0.60). In 18 months ASQ: SE questionnaires the internal reliability was even lower (α=0.51).

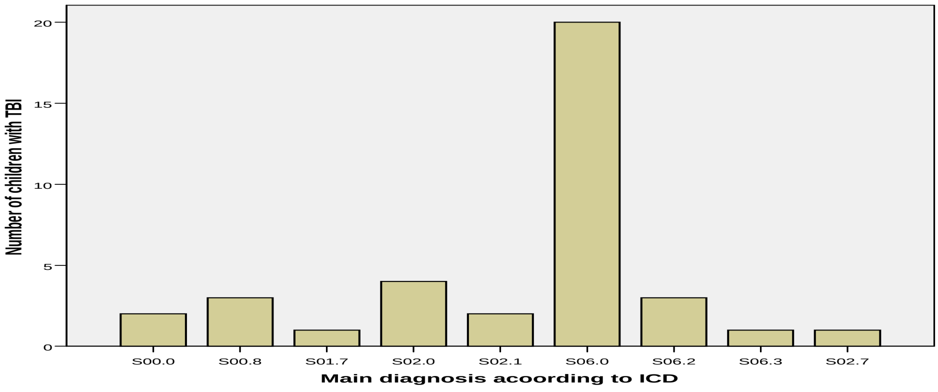
Demographic and clinical data and pre-injury screening variables

According to diagnostic criteria presented above, mild TBI was diagnosed in 27 children, moderate TBI in 4 children and severe TBI in 6 children. Main demographic and clinical data of subjects is presented in Table 2.

Table 2. Subjects' characteristics

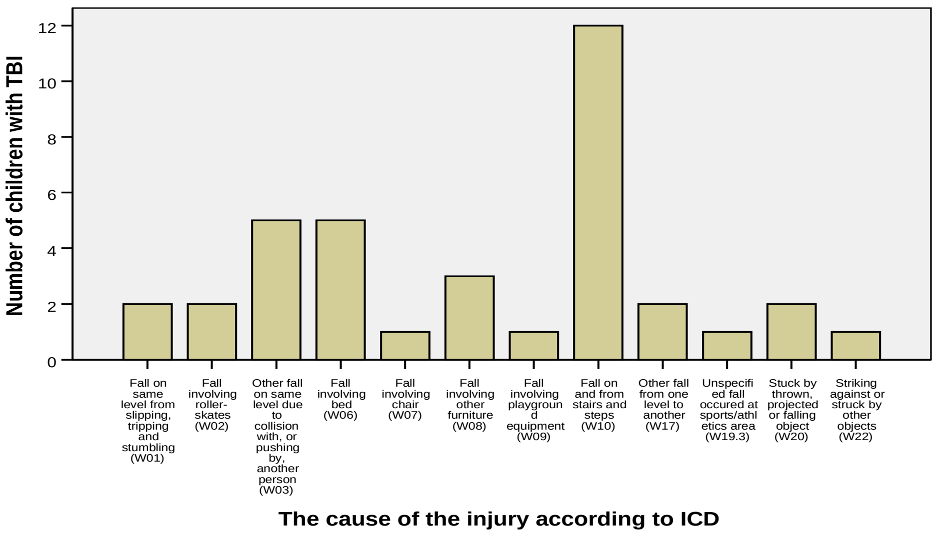
Patient	Sex	Age at the time of TBI	Mother's education	Father's education	Main diagnosis according to ICD	Glasgow Coma Scale score	Trauma severity	The cause of the injury according to ICD
N1	male	29	Secondary	Secondary	S06.0	15	mild	W10
N2	male	29	Secondary	Secondary	S00.8	15	mild	W22
N3	male	28	Secondary	Secondary	S06.0	15	mild	W20
N4	female	30	Higher	Higher	S02.1	15	severe	W02
N5	male	4	Secondary	Secondary	S06.2	14	moderate	W10
N6	female	16	Higher		S06.0	15	mild	W08
N7	female	55	Higher	Higher	S06.0	15	mild	W10
N8	female	16	Higher	Secondary	S00.8	15	mild	W06
N9	male	56	Secondary	Secondary	S01.7	15	mild	W10
N10	female	25			S06.0	15	mild	W03
N11	male	5	Primary		S00.8	15	mild	W03
N12	male	38	Primary	Secondary	S02.0	15	moderate	W20
N13	male	40	Primary		S06.0	15	mild	W01
N14	male	59	Higher	Secondary	S06.0	15	mild	W03
N15	male	63	Higher	Higher	S02.0	15	severe	W10
N16	male	49	Primary	Primary	S02.1	13	severe	W17
N17	male	50	Secondary	Primary	S06.0	15	mild	W09
N18	male	16			S00.0	15	mild	W08
N19	female	4	Secondary	Secondary	S06.0	15	mild	W06
N20	female	30	Secondary	Higher	S06.0	15	mild	W10
N21	male	17	Higher	Higher	S06.0	15	mild	W03
N22	male	10	Higher	Higher	S06.0	15	mild	W17
N23	female	11	Higher	Higher	S06.2	11	severe	W10
N24	male	58	Secondary	Secondary	S06.2	15	moderate	W01
N25	female	48	Higher	Secondary	S06.0	15	mild	W10
N26	male	12	Primary	Secondary	S06.3	13	severe	W06
N27	female	65	Higher	Secondary	S06.0	15	mild	W06
N28	female	13	Secondary	Secondary	S06.0	15	mild	W08
N29	female	64	Higher	Secondary	S06.0	15	mild	W19.3
N30	male	50	Primary	Secondary	S02.0	15	moderate	W10
N31	male	65	Higher	Secondary	S06.0	15	mild	W10
N32	male	22	Secondary	Secondary	S06.0	15	mild	W03
N33	female	11	Secondary	Secondary	S06.0	15	mild	W02
N34	female	26	Higher	Higher	S00.0	15	mild	W06
N35	male	24	Secondary	Higher	S02.7	14	severe	W10
N36	male	32	Higher	Secondary	S06.0	15	mild	W07
N37	male	58	Primary		S02.0	15	moderate	W10

These injuries resulted in the following diagnoses: 20 of the children (54.1%) in the present sample were diagnosed as having a concussion (S06.0), 4 children had fracture of the convexity of skull (S02.0), 3 children had diffuse axonal injury (S06.2), 3 had superficial injury to the other part of the brain (S00.8), 2 had fracture of the base of the skull (S02.1) and another two had superficial injury to the scalp. Multiple open wounds of the head (S01.7), multiple fracture involving skull and facial bones (S02.7) and focal brain injury (S06.3) were all diagnosed in one child (see graph 1).



Gaph 1. The main TBI diagnosis of subjects in the present study

The main causes for TBI in the present sample involved falls on and from stairs and steps (W10). The second and third most common causes of TBI in a present sample were falls from the same level due to collision, or pushing by another person (W03) and falls from the bed (W06), both types accounted for 13.5% of the cases. Three children (8.1%) were injured from falls involving other furniture (W08). Other fall from one level to another (W17), a fall involving roller-skates (W02) and a fall at same level from slipping, tripping and stumbling each caused the injuries of two children (5.4%). Another two children sustained TBI because of being struck by thrown, projected or falling object (W20). Fall from the chair (W07), fall involving playground equipment (W09), unspecified fall occurred at sports/athletic area (W19.3) and strike against or struck by other object (W22) all caused the injury of one child.



Graph 2. The causes of injury among subjects of the present study

Study I

Pre-injury differences in social-emotional behavior between TBI group and control group children.

When all age groups were included to the analysis, trend was seen between TBI group and in control group, suggesting that children from TBI group have more pre-ijury social and emotional problems (*U*=1081.0, N1=74, N2=37, p=0.072). The following subtests' scores examination showed statistically significant differences in two behavioral areas in favor of control group. Mann-Whitney *U*-test found that the scores in self-regulation subscale were significantly higher in children from TBI group when compared to children from control group (*U*=869, N1=74, N2=34, p=0.02), indicating more problems in self-regulation domains among children in the TBI group. Statistically significant difference between control group and TBI group in autonomy domain was also seen (*U*=623.5, N1=58, N2=29, p=0.049), again suggesting more problematic behaviors in TBI group children. No statistically significant differences or noteworthy trends between TBI and control groups children were found in compliance, communication, adaptive functioning, affect and interaction subtests.

Pre-injury social-emotional behavior in children with TBI in different age groups

To examine pre-injury social-emotional behavior in different age groups, children with TBI were divided into 8 subgroups according to ASQ: SE questionnaires age range. These different age groups were compared separately with age, sex and parents' education matched controls using the Mann-Whitney *U*-test for statistical data analysis (see Table 3).

In the 60 months age group, *U*-test detected that children from TBI group were reported to have more problematic behaviors concerning autonomy (*U*=36.0, N1=18, N2=9, p=0.011). In other ASQ: SE sub-domains examined, no significant differences were revealed.

In the 48 months subgroup, no statistically significant differences between TBI group and control group were revealed in any examined domains.

36 months old subgroup there were too few children (n>4) in TBI group, therefore Mann-Whitney test could no be performed.

30-months old TBI group children's overall social and emotional behavior two weeks before the injury was reported to be more problematic than their age matched peers (*U*=8.0, N1=12, N2=6, p=0.008). Problems appeared especially in self-regulation (*U*=6.0, N1=12, N2=6, p=0.004) and in communication (*U*=16.5, N1=12, N2=6, p=0.029).

The non-parametric Mann-Whitney *U*-test did not reveal any significant differences between TBI and control group children neither in overall social-emotional behavior nor in any subtests in 24 months old sub-group. The only single item which differed significantly TBI and control groups children was „Do you and your child enjoys mealtimes together" (*U*=6.0, N1=8, N2=4, p=0.047), suggesting more difficulties in while eating in TBI group children.

Table 3. Social and emotional behavior: a comparison between TBI and control group

Age in months	ASQ: Sub domains	Single item	Mann-Whitney *U-test*				
			U	**Z**	**N1**	**N2**	**p**
60	**Social-emotional behavior**		54.0	-1.39	18	9	0.163
	Self-regulation		56.6	-1.23	18	9	0.197
	Compliance		59.5	-0.69	18	9	0.488
	Adaptive functions		75.0	-0.35	18	9	0.727
	Autonomy		36.0	-2.54	18	9	0.011
		Careless when exploring new places	35.5	-2.65	18	9	0.008
	Affect		62.0	-1.17	18	9	0.241
	Interaction		55.0	-1.39	18	9	0.162
		Takes turns and shares	54.0	-1.92	18	9	0.054
48	**Social-emotional behavior**		10.0	-1.02	8	4	0.305
	Self-regulation		11.5	-0.819	8	4	0.413
	Compliance		14.0	-0.82	8	4	0.480
	Communication		16.0	0.00	8	4	1.000
	Adaptive functions		11.0	-1.12	8	4	0.264
		Stays dry during the day	8.0	-2.09	8	4	0.037
	Autonomy		16.0	0.00	8	4	1.000
	Affect		12.5	-0.68	8	4	0.498
	Interaction		10.5	-0.99	8	4	0.323
36*					4	2	
30	**Social-emotional behavior**		2.5	-2.66	12	6	0.008
	Self-regulation		6.0	-2.88	12	6	0.004
		Has perseverative behaviors	12.0	-3.12	12	6	0.002
		More active than peers	19.5	-3.12	12	6	0.091
		Stays with activities	21.0	-1.95	12	6	0.051
		Moves from one activity to next	21.0	-1.95	12	6	0.051
	Compliance		36.0	0.00	12	6	1.000
	Communication		16.5	-2.8	12	6	0.029
	Adaptive functions		23.5	-1.29	12	6	0.196
		Has eating problems	20.0	-2.06	12	6	0.004
		Lets know/uses words when hungry, sick, tired	20.0	-2.06	12	6	0.004
		Follows when pointed	24.0	-2.06	12	6	0.004
	Autonomy		34.5	-0.15	12	6	0.881
	Affect		36.0	0.00	12	6	1.000
	Interaction		20.5	-1.50	12	6	0.134
		Too friendly with strangers	15.0	-2.68	12	6	0.002

24	**Social emotional behavior**		12.5	-0.60	8	4	0.549
	Self-regulation		11.5	-0.83	8	4	0.405
	Compliance		12.0	-1.14	8	4	0.157
	Communication		14.0	-0.52	8	4	0.600
	Adaptive function		14.5	-0.28	8	4	0.784
	Autonomy		16.0	0.00	8	4	1.000
	Affect		15.0	-0.18	8	4	0.858
	Interaction		7.5	-1.48	8	4	0.140
		Enjoys mealtimes together	6.0	-1.98	8	4	0.047
18	**Social-emotional behavior****		3.0	-2.26	8	4	0.024
	Self-regulation		16.0	0.00	8	4	1.000
	Compliance		10.0	-1.35	8	4	0.176
	Communication		12.5	-0.71	8	4	0.475
	Adaptive functions		13.0	-0.61	8	4	0.540
	Autonomy		10.0	-1.35	8	4	0.176
	Affect		10.0	-1.34	8	4	0.181
	Interaction		11.5	-0.82	8	4	0.410
12	**Social-emotional behavior**		8.5	-2.04	10	5	0.041
	Self-regulation		17.5	-0.94	10	5	0.371
		Can calm down by himself	6.0	-2.54	10	5	0.011
	Compliance***						
	Communication		15	-1.50	10	5	0.254
		Listens; turns to look, smiles; looks	10	-2.07	10	5	0.008
	Adaptive functions		18	-0.89	10	5	0.440
	Affect		12.0	-2.06	10	5	0.040
	Interaction		17.7	-1.00	10	5	0.316
		Stiffen and arches back	15.0	-2.64	10	5	0.038
6	**Social-emotional behavior**		7.5		6	3	0.694
	Self-regulation		8.0	0.79	6	3	0.788
	Compliance***						
	Communication		7.5	-0.71	6	3	0.480
	Adaptive functions		4.5	-1.39	6	3	0.165
	Autonomy***						
	Affect		6.0	-1.07	6	3	0.285
	Interaction		8.0	-0.35	6	3	0.724

*Because of a small number of children with TBI in 36 months old group (n=2), statistical analysis was not performed for this age-group
**Children with TBI performed better than control group children
***Not assessed in this age group

In 18 month old sub-group, the *U*-test revealed a significant difference between the TBI group and control group in overall social-emotional behavior (*U*=3.0, N1=8, N2=4, p=0.024), but it is noteworthy that control group children were evaluated to perform worse than children from TBI group. No other significant differences or even trends in any of the subtests or single item scores were revealed.

12 months old children's social-emotional behavior within 2 weeks before the injury was evaluated to be significantly worse than of age matched controls (*U*=8.5, N1=10, N2=5,

p=0.041). More problematic behaviors were reported in affect sub-domain (*U*=12.0, N1=10, N2=5, p=0.04).

In the youngest age group, 6 months, the Mann-Whitney *U*-test did not reveal any significant differences between TBI and control group in overall social-emotional behavior. Subscales examination and single item examination were of no help in discriminating these two groups.

Pre-injury sex differences in social and emotional behavior

When boys and girls from TBI group were compared according to their pre-injury social and emotional behavior, it became evident that boys' parents had reported significantly more problems in their child's self-regulation (*U*=96.0, N1=23, N2=14, p=0.042) and compliance (*U*=63.0, N1=21, N2=13, p=0.009) than girls' parents. In the control group, no such gender differences in any of domains were revealed.

When boys in the TBI group were compared to boys from control group, self-regulation (*U*=272.5, N1=46, N2=23, p=0.001) and autonomy (*U*=232.5, N1=38, N2=19, p=0.029) appeared to be problematic areas for TBI group boys. The trends suggest a difference between TBI group and control group in overall social-emotional behavior (*U*=395.0, N1=46, N2=23, p=0.088) and in compliance (*U*=436.5, N1=42, N2=21, p=0.086). Girls in the TBI group and control group differed only in adaptive functions (*U*=112.0, N1=28, N2=14, p=0.024) in respect to control group girls who were reported to perform better.

Pre-injury differences in social and emotional behavior according to parents' education

TBI group children were regrouped according to parents' education and the grouping criteria presented earlier. ASQ: SE total scores and subtest scores were compared between these 5 groups (see Table 5).

Table 4. Children with TBI grouped according to parents' education

Parents' education	Sex		Total
	male	female	
Primary-primary (1)	4	-	4
Primary-secondary (2)	4	-	4
Secondary-secondary (3)	9	3	12
Secondary-higher (4)	2	5	7
Higher-higher (5)	3	5	8
Total	22	13	35*

* For two children in TBI group data concerning parents' education was not available

Noteworthy inter-group difference was revealed in adaptive functions sub-scale when using Kruskal-Wallis one-way ANOVA test for statistical analysis (*H*=10.83, df=4, p=0.028). As the Kruskal-Wallis test does not reveal how the groups differ (Chan & Walmsley, 1997) Mann-Whitney test was used for pairwise comparison. *U*-test found that parents with higher education reported more problems in their child's adaptive functions compared to parents who both had secondary education (*U*=12.5, N1=12, N2=8 p=0.005). Relatively few problems in their child's adaptive functions were reported by parents who belonged to the group 4 (one parent had secondary education and one parent had higher education) compared to parents from group 5 (both had higher education) (*U*=16.0, N1=8, N2=7, p=0.053). Parents from group 1 (primary education) were also keen on reporting problems in their child's adaptive functions (*U*=8.0, N1=11, N2=4, p=0.066), compared to parents who belonged to group 2 (one parent had primary education and another parent secondary education).

Study II

In Study II, 19 children with TBI were re-evaluated with the age appropriate ASQ: SE questionnaires.

Mean age at second evaluation was 38.84 months (SD=17.62). There were 14 children with mild TBI, 1 child with moderate TBI, and 4 children with severe TBI. 10 of these children were diagnosed with concussion (S06.0), two had suffered superficial injury of head (S00.0), an other two had superficial injury to other part of the brain (S00.08). Fracture of base of skull (S=02.1) were diagnosed in two children while diffuse brain injury (S06.2), fracture of convexity of the skull (S02.0), and multiple open wound of the head (S01.7) were all diagnosed in one child in prospective study group. CT or MRI scan were performed during hospitalization to examine the amount of brain damage.

Table 5. Clinical data of subjects in Study 2.

Trauma severity			**Sex**		Total
			male	**female**	
mild	**Imaging findings**	no pathology	5	9	14
moderate	**Imaging findings**	no pathology	1	-	1
severe	**Imaging findings**	bilateral occipital	2	-	2
		frontal	-	1	1
		right parieto-occipital	-	1	1
Total			8	11	19

CT and MRI showed no brain pathology in 15 children whereas two children had lesions in bilateral occipital areas, one in right parieto-occipital areas and one in frontal areas.

Post-injury social and emotional behavior – a comparison between TBI group and control group

The second evaluation 9 months after the injury revealed noteworthy trend between TBI and control group in overall social-emotional behavior (*U*=254, N1=38, N2=19, p=0.072) and one subtest score differed substantially. Compared to controls, reevaluated TBI children were reported to have more problems in interaction with other people (*U*=210, N1=38, N2=19, p=0.01). The trend towards problematic behaviors was still seen in self-regulation (*U*=254, N1= 38, N2=19, p=0.058) and in autonomy (*U*=353, N1=36, N2=18, p=0.071). Comparison between different age groups in Study II was not proper as sub-groups were to small (n>4).

Sex related differences in social and emotional behavior 9 months post-injury

When TBI group boys and girls were compared with Mann-Whitney *U*-test, it became evident that on second evaluation boys with TBI were again much worse in self-regulation than girls (*U*=15.5, N1=8, N2=11, p=0.018). When boys from the TBI group were compared to boys from control group 9 months after the injury, TBI group boys showed significantly worse results in overall social emotional behavior (*U*=24, N1=16, N2=8, p=0.014), in self-regulation (*U*=29.5, N1=16, N2=8, p=0.034), in autonomy (*U*=16.5, N1=14, N2=7, p=0.014) and in interaction with other people (*U*=11.0, N1=16, N2=8, p=0.001).
On second evaluation girls from the TBI group and girls form control group did not differ significantly in any of examined domains.

Differences in social and emotional development

Wilcoxon matched-pair test was used to assess the change within groups. Within TBI group, the Wilcoxon matched-pair test did not reveal significant change in ASQ: SE overall score or did any of the changes in sub-domains scores reached the significance level. The trend suggesting more problematic behaviors after time was seen in the interaction sub-domain (Wilcoxon: *N*=19, z=-1.91 based on negative ranks, p=0.056).
In control group neither ASQ: SE overall score or none of the subtest scores showed significant change or even a noteworthy trend of a change after 9 months. When Wilcoxon matched-pair test was computed separately to brain injured boys and girls, significant changes in some subtests were revealed. Among boys with TBI, the Wilcoxon matched pair test found a significant decline in test scores after 9 months in autonomy (Wilxoxon: z=-2.27 N=8, p=0.027) and in interaction (Wilcoxon: z=-2.19, N=8, p=0.028). Among brain injured girls

group communication skills (Wilcoxon: z=-1.78, N=11, p=0.074) and adaptive functions (Wilcoxon: z=-1.78, N=11, p=0.074) showed decline trend.

To assess the change in ASQ: SE total score and subtest scores between groups, Mann-Whitney *U*-test was performed on the score difference of second and first evaluation. Again, no significant results were detected which would suggest differential social-emotional development of children with TBI, but trend in worse interaction (*U*=12, N1=38, N2= 19, p=0.053) became evident in this comparison too. When Mann-Whitney *U*-test was performed separately to boys and girls, the worst outcome after 9 months was again seen in boys with TBI. Compared to age, sex and parents' education matched controls, boys with TBI showed a trend of decline in overall social-emotional behavior over time (*U*=38.5, N1=16, N2=8, p=0.058) significant declines in autonomy (*U*=18.0, N1=14, N2=7, p=0.02), and in interaction with other people (*U*=28.5, N1=16, N2=8, p=0.014). Overall social and emotional development in girls with TBI did not differ from their age, sex and parents' education matched peers. No statistically significant differences or even slight trends suggesting a worse outcome for TBI group girls were seen.

Post-injury social and emotional behavior and trauma severity.

Spearmans' non-parametric *rho* correlation was used to assess the relation between post-injury social and emotional behavior and trauma severity. Correlations were computed between trauma severity and all 9 months post-injury ASQ: SE subtest and between trauma severity and 9 months post-injury ASQ: SE total score. Strong statistically significant positive correlation occurred only between trauma severity and affect sub-domain, indicating more problems in affective behavior in more severely injured children (rho=0.582, p=0.009).

DISCUSSION

The aim of the present study was to examine the pre-injury social and emotional behavior and changes in social-emotional behavior after injury in infants and preschoolers with childhood TBI.

As hypothesized, children who sustained TBI in early childhood had exhibited problematic social and emotional behaviors already before the injury. These findings are consistent with previous findings by Goldstrhom and Arffa (2005), which suggested that in comparison to non-injured children, preschool-aged children with TBI have higher rates of premorbid behavioral difficulties.

In a present study, children with TBI exhibited substantially more problems in self-regulation and autonomy already before the injury giving reason to think that poorer autonomy and self-regulation skills may be linked to future TBI.

Self-regulation is thought to be the major predictor of social competence (Campell, 1995; Olson *et al.*, 2005) and is characterized as multifaceted construct that is often viewed as biologically based attribute and governed by the prefrontal cortex (Luria, 1973). Regulatory deficits including poor inhibitory control, as well as deficits in planning and organization, have been connected to lesions to the orbitomedial and dorsolateral prefrontal cortex (Stuss, 1992). While the disruption in the structure and functional organization of the prefrontal cortex is common after TBI (Bigler *et a.*,2001), Ganesalingam *et al.* (2006) who found children with TBI performing relatively poorer in self-regulation, argued that worse outcome in children with TBI in self-regulation may be due to brain damage associated with TBI in areas mentioned above. Our findings suggest that the underlying deficit in self-regulation is already present before the injury and therefore making these children much more vulnerable to accidental injuries.

According to our findings, children with TBI show pre-injury deficit not only in self-regulation, but also in autonomy. It is well known that children, who have difficulties in keeping away from danger and who are considered to be too independent are in higher risk of participating in accidents.

Our findings suggest that there are different danger signs for TBI in different age groups. For example 60 months old children from TBI group were reported to have more problems in autonomy sub-domain than their matched controls: they were notably more careless, when exploring new places. Lower ability to perceive danger is well connected with accidental injuries and hereby supports the argument presented above.

While discussing the differences in pre-injury social and emotional behavior in different age group however, one cannot forget that most of the age groups consisted of only relatively few children and therefore the generalizations to entire population are not appropriate and these results describe mainly the present sample. Same notion has to be kept in mind, while interpreting the results about pre-injury social and emotional behavior between TBI group children with different parental education. In a present sample only differences in adaptive functions between TBI children grouped according to parents' education came evident. It is surprising in some extent, that more problematic adaptive functions were reported by higher educated parents. One explanation is of course, is that TBI group children with higher educated parents have more problems in adaptive functions and children with parents who have secondary education do better. Second explanation could be that higher educated parents may have higher expectations to their child's adaptive skills.

Many studies report that boys are more prone to suffer childhood accidental injuries than girls (Langlois *et al.,* 2006), but there is not much research focusing on gender differences and gender related effects on emotional and social behavior pre- and post-injury. Our finding, that boys from TBI group show more pre-injury self-regulation problems than girls from TBI group, is relatively novel. In further extent, while the TBI group boys differ from non-injured peers in worse self-regulation and compliance, the girls from TBI group showed slightly more problems in adaptive functions than their uninjured peers. This finding suggests that the alarming behaviors placing a child into risk group for childhood TBI may be somewhat different for boys and girls.

These gender differences in pre-injury social and emotional behavior are especially important for parents and preschool teachers, but also important for larger communities. As reported previously by Ventsel *et al.,* (2008) the incidence rate for traumatic brain injuries among infants and toddlers is especially high and there is an urgent need for governmental prevention program to reduce TBI in children in Estonia. The need to create teaching programs for parents and other adults working with children to make them more aware of risks of injuries is enormous. Knowledge about gender specific social and emotional risky behaviors for TBI, can give adults who deal with children on daily basis specific observable information and therefore gives them the opportunities to obviate possible injuries.

A prospective study revealed that 9 months after injury, children with TBI had more problems in interaction with other people. Inappropriate social responses to peers, parents and adults were seen in greater distinct in injured children. These finding are in line with the findings of Dennis Guger, Roncadin, Barnes, & Schachter (2001), who studied the affective communication in children with TBI and found that children with TBI performed especially poorly in understanding statements involving ironic criticism or emphatic praise. Max *et al.* (2006) reported more tactless comments, inappropriate sharing of a personal information, aggressive behavior and overall affective liability in injured children. As the difficulties in self-regulation and autonomy were still notable 9 months after the injury, the interplay of poorer self-regulation, autonomy and interaction with peers and other people will put the children with TBI in a much worse situation in creating and obtaining effective and rewarding social relationships.

In our study, boys and girls showed somewhat different problems in social and emotional behavior 9 months post-injury. Boys with TBI showed significant decline in autonomy (p=0.027) and in interaction over time (p=0.02), while girls showed declines in adaptive functions (p=0.074) and communication skills (0.074). Among control group children no such gender differences or any declines were present. Adaptive dysfunction although relative unexplored in the research literature, remains among the most common complaints identified by children and their families post-injury (Anderson *et al.,* 2006; Anderson *et al.,* 2001). Anderson *et al.* (2006) have further suggested that during the 30-months after injury, adaptive skills show constant decline in children with more severe TBI. Anderson (2006) in his study however did not bargain for sex differences.

In our study we found strong associations between trauma severity and affect sub-domain in nine months post injury. More severely injured children were having more problems in affective behavior. This finding gives further proof to the assumptions, that regulation of affective states may be significantly impaired in children with moderate and severe brain trauma (Max *et al.,* 2006).

It has been argued (Perna, 2002) that emotional and behavioral problems become more apparent with the onset of adolescence. In adolescence, interaction becomes more complex through psychosocial development, marked by greater personal and social awareness, and the need for independence. The importance to understand ironic criticism and underlying meanings is increasingly important in adolescence interaction (Turkstra, McDonald, & Depompei, 2001). Therefore children with early childhood TBI may experience social and emotional difficulties much later in life.

According to our findings, children with TBI show significantly more pre-injury problems in social and emotional behavior and these difficulties, particularly in boys with TBI showed decline in overall social-emotional behavior and in autonomy and interaction with other people.

Evaluation of the injured child’s pre-injury behavior may help to identify those children needing special assistance and intervention already in an acute phase of TBI. Social and emotional development of all children with TBI must be followed carefully at least till the adolescence age. Parents’ of children with TBI must be provided constant feedback and newest information about the danger signs for more serious emotional and behavioral problems. The gender differences in pre- and post-injury social and emotional behavior must certainly be addressed while educating parents. Parents have to be encouraged to seek professional help and intervention in an early stage of the emerging problems.

The screening instrument ASQ: SE used in present study seems to be suitable method for helping to identify problems in social-emotional behavior and social-emotional development in young children with TBI.

Limitations and further directions

The current study was characterized by several methodological limitations.

One important limitation of our study is the fact that in the prospective evaluation of social and emotional behavior and social and emotional development, data about substantial number of children with TBI was unavailable. Data in our follow-up study could be biased, and the findings may not generalize to the entire population of children with TBI. It is possible, that because of the high number of drop-outs, some important associations were not revealed.

Because of too few children in a prospective study were not able to study the associations between lesion site and initial social-emotional outcome and between lesions site and socio-emotional development. Brain injury is more diffuse process and there are relatively few children with focal injuries, therefore distinguishing between lesion sites and specific social and emotional outcome after TBI remains one of our next goals as we continue childhood brain injury research in Estonia.

Because of small sample size in a prospective study we also could not evaluate the effect parental education may have on post-injury social and emotional behavior. Ganesalingam *et al.* (2006) have reported parental, especially mother's education, to be one of the most important factors which affects child's initial socio-behavioral outcome after TBI. Other researchers have argued that many important psychosocial factors (e.g. parents' marital problems, mental disturbance, higher life stress, fewer family resources, poorer family functioning) increase frequency of child's emotional and behavioral problems following childhood TBI (Taylor, Yeates, Wade, Drotar, Stancin, & Minchin, 2002; Yates *et al.*, 2004). Best outcomes are reported among children who come from families with better socio-economical status, less family stress, high levels of family cohesion and low levels of parental control. Therefore in our continuing research we will also try to take these measures into consideration.

CONCLUSIONS

This study assessed pre- and post-injury social and emotional behavior in infants and toddlers with childhood TBI.

The results were in line with previous studies which suggest that childhood TBI affects not only children's cognitive abilities, but social and emotional functioning as well. The social-emotional function most affected of TBI was interaction with other people, but children with TBI showed post-injury decline yet in self-regulation and autonomy.

For boys significant decline was evident in self-regulation and interaction with other people and for girls TBI had affected most these children's adaptive skills and communication skills. Children with more severe TBI exhibited more difficulties in affective states.

We also found that children with TBI exhibited more problematic social-emotional behavior already before the injury. Pre-injury difficulties were evident in self-regulation and autonomy.

As hypothesized, girls had fewer problems in pre-injury social and emotional behaviors than boys. When compared to group of uninjured children, pre-injury self-regulation and compliance problems were especially notable for TBI group boys while TBI group girls had more difficulties with adaptive functions. The finding that poorer self-regulation and compliance among boys and worse adaptive functions among girls are well connected to future TBI emphasizes the importance of early detection of specific social and emotional problems. Screening instrument used in a present study is one of the possibilities of early low cost and effective detection of these specific problems.

ACKNOWLEDGEMENTS

I am grateful to all the children and parents who participated in this study and to the doctors and nurses who work in Tartu University Hospital's Children's Clinic in Department of Neurology and contributed to completion of the study. I am very grateful to my supervisor Anneli Kolk for her comments, encouragement and her continuous belief in me. I would also like to thank my family and friends and everybody, who helped with present thesis, especial gratitude to Gerli Ventsel and Jüri Reimand for his patience and support.

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