ELSEVIER

Child Abuse & Neglect 32 (2008) 415–428

Child Abuse & Neglect

Comparative study of the cognitive sequelae of school-aged victims of Shaken Baby Syndrome☆

Annie Stipanicic*, Pierre Nolin, Gilles Fortin, Marie-France Gobeil

Department of Psychology, University of Quebec at Trois-Rivières, Child and Family Development Research Unit, Quebec, Canada

Received 18 May 2006; received in revised form 18 July 2007; accepted 25 July 2007

Abstract

Objective: Shaken Baby Syndrome (SBS) is now recognized as being the main cause of severe traumatic brain injury in infancy. However, our understanding of the impact of this type of abuse on child development remains sketchy. The main objective of the current study was therefore to shed light on the cognitive dysfunctions that are particular to SBS victims once they are school-aged.

Method: A clinical group was formed of 11 children diagnosed with SBS who had been admitted between 1988 and 1999 to a tertiary pediatric hospital in Quebec, Canada. The children were matched for age, gender, socio-economic status, and family composition to 11 healthy Quebec children, who made up the control group. A battery of composite tests was developed to assess the children's main cognitive functions and was administered individually to the 22 children. A univariate *t*-test was used to compare the performances of the two groups.

Results: The mean age of the children in the clinical and control groups at the time of the assessment was 87.64 months and 90.18 months, respectively. Pairing and birth data were equivalent for both groups. Significant weaknesses were noted in the clinical group for intelligence quotient (IQ), working memory, mental organization, alternation, and inhibition. These deficits seemed to have a greater impact on the verbal sphere of the children's mental functioning.

☆ The first author was supported by a grant from the Social Sciences and Humanities Research Council of Canada (SSHRC) and the *Fonds pour la formation pour les chercheurs et l'aide à la recherche* (FCAR), a Quebec research fund.

* Corresponding author address: Department of Psychology, University of Quebec at Trois-Rivières, P.O. Box 500, Trois-Rivières, Quebec, Canada G9A 5H7.

doi:10.1016/j.chiabu.2007.07.008

Conclusion: Primary results point to the anterior cerebral regions of the brain as the principal site of dysfunctions that persist years post-trauma. It is important to consider these results longitudinally, even in children apparently less extensively affected, since the frontal regions only reach maturity at the end of adolescence.

Keywords: Shaken Baby Syndrome; Non-accidental head injury; Neuropsychology; Executive functions

Introduction

Shaking injuries inflicted on a developing brain represent a unique form of brain injury that appears almost exclusively in young children. The first clinical observations of such trauma date back to the end of the 19th century, however it was doctors Caffey (1946, 1972, 1974) and Guthkelch (1971) who made the link between the pathological picture and the occurrence of physical maltreatment. A brutal succession of accelerations and decelerations applied to the brain within the braincase results in the appearance of specific cerebral and ophthalmic lesions. This is typically seen in infants, often aged 4–8 months, who present neurological damage of varying severity with no external signs of serious trauma. A radiological and ophthalmologic investigation shows, in the absence of other signs of blood or infectious disorders or a history of significant trauma, the presence of subdural hemorrhagic collections, cerebral edema and retinal hemorrhage (Jenny, Hymel, Ritzen, Reinert, & Hay, 1999). A complete skeletal X-ray will often reveal the presence of relatively recent fractures to the ribs or long bone extremities.

It is difficult to ascertain the extent of SBS, particularly because of the less-than-rigorous terminology and the few studies conducted to date. The most recent study on the incidence of SBS is the work of Barlow and Minns (2000). They estimated the annual incidence of NAHI in Scottish babies under one year of age at 24.6/100,000. In their study, the term NAHI appears to be synonymous with SBS. A Canadian study by King and MacKay (2000) identified 364 cases in a retrospective investigation conducted from 1988 to 1998 in 11 tertiary pediatric care facilities (King, MacKay, & Sirnick, 2003). These facilities represent approximately 85% of the tertiary pediatric beds in Canada, 9% (33) of which are at the Centre Hospitalier Universitaire Ste-Justine (CHUSJ), a major children's hospital in Montreal, Quebec. As part of a national Health Canada study on the incidence of reports of child abuse and neglect, Trocmé et al. (2001) found that among the cases investigated for suspected SBS in 1998, 189 (32%) were corroborated and 165 were recorded as presumed because of lack of sufficient evidence. It is important to keep in mind that many, often less severe, cases go unreported because of the stigma associated with reporting abuse and the lack of external signs left by the trauma. Furthermore, SBS cases may also be part of a broader problem of physical maltreatment and therefore not be isolated in the studies conducted (Health Canada, 2001; Jenny et al., 1999; Trocmé et al., 2001).

The consequences of SBS are a huge cause for concern. A large proportion—40–100% of the children—present with a relatively altered state of consciousness upon admission to the emergency ward (Bonnier, Nassogne, & Evrad, 1995; Brenner, Fisher, & Mann-Gray, 1989; Goldstein, Kelly, Bruton, & Cox, 1993; Haviland & Russell, 1997; Ludwig & Warman, 1984). Studies have shown that approximately one third of SBS children die as a result of their injuries (Brenner et al., 1989; King et al., 2003; Ludwig & Warman, 1984). When SBS victims do survive, they are at risk of presenting multiple deficits, primarily neurological: motor deficits in 7–25% of cases, sensory deficits (vision) in 5–86% of cases, and epilepsy in 25–80% of cases (Bonnier et al., 1995; Brenner et al., 1989; Duhaime, Christian, Moss, & Seidl,

1996; Fisher & Allasio, 1994; Goldstein et al., 1993; Ludwig & Warman, 1984). According to a review of medical charts conducted by King's team of researchers (2000, 2003), 55% of survivors presented a range of neurological damage and only 35% showed normal vision. Only 22% were considered to meet normal health criteria upon being discharged. The *Glasgow Outcome Scale* (GOS), administered on average 1.3 months post-diagnosis by Ewing-Cobbs' team (1998), revealed a proportion of 15% with severe dysfunctions (dependency in daily activities, presence of physical and cognitive disabilities) and a proportion of 65% with moderate dysfunctions (functional autonomy but the presence of disabilities that hinder daily activities) in IHI children. Furthermore, psychometric measures revealed that 45% of these children presented an intellectual performance in the deficient range (Ewing-Cobbs et al., 1998).

Given the limited number of studies and the numerous methodological limitations involved, our knowledge of the impact of neurological damage on long-term child development is sketchy. In addition to inconsistent terminology that limits comparisons, the majority of studies present only a retrospective review of the victims' medical histories. Studies that administered the GOS in a follow-up 5–9 years post-trauma still show a high level of disability; a moderate to high level was found in 40–65% of cases (Barlow, Thompson, & Minns, 1999; Duhaime et al., 1996). Other studies underscore the persistence and even aggravation of initially precarious neurological situations (Bonnier et al., 1995; Ewing-Cobbs, Prasad, Kramer, & Landry, 1999; Fisher & Allasio, 1994; Haviland & Russell, 1997; Sinal & Ball, 1987). Using standard psychometric instruments, Barlow's team of researchers (1999) determined that among 30 NAHI children, 13 presented motor deficits, 8 showed visual problems and 10 presented language delays or problems on average 4.4 years after beginning medical treatment. Furthermore, behavior problems affect nearly half of the victims (Barlow, Thompson, Johnsons, & Minns, 2005).

To date, few studies have investigated the cognitive outcome of SBS. Of these, only a minority examined victims based on live interviews and standardized measures. The purpose of the current study is to provide a detailed examination of the long-term cognitive sequelae of a group of children hospitalized as a result of SBS, testing the hypothesis that SBS children would show a poorer performance than normal children.

Method

Participants

Medical files were examined of child victims of non-accidental brain injury aged 0–36 months, admitted to CHUSJ between 1988 and 1999. Given that SBS patients present with a wide range of clinical signs, the subjects selected had to meet the following inclusion criteria: the diagnosis had to have been confirmed by a team of maltreatment specialists composed of pediatricians, a neurologist, a neuroradiologist and a social worker, as a case of SBS with or without impact based on at least two of the following three criteria: (1) presence of subdural hematoma (SDH) or subarachnoid hemorrhage (SAH); (2) presence of retinal hemorrhage (RH); (3) a credible account of shaking reported. Thirty three selected files were reviewed using the modified Pediatric Performance Category Scale at discharge (King & MacKay, 2000), 2 (6%) were dead, 13 (39%) were in a vegetative to severe neurological disability state, 17 (52%) were having a moderate to mild disability and 1 (3%) was normal. Of the confirmed cases, only subjects presenting the minimum neurosensory abilities required for completing paper-and-pencil tasks (intellectual potential estimated at above the threshold for moderate deficiency, absence of blindness, absence of deafness, functional usage of one of the two upper limbs) were selected for the study. Several charts had to be

rejected because it was impossible to locate the child based on the data available or because of reluctance on the part of the child's caretaker. In all, 10 of 18 subjects who met the inclusion criteria agreed to take part in the study. Another case, fulfilling the same criteria, but from another institution was also included.

The medical records of the SBS children were reviewed by a neuro-pediatrician specialized in child maltreatment. A structured data collection form had been developed for that purpose, based on the data collection form used in the cross-Canada SBS study conducted by King and his colleagues (2000, 2003). Computed tomography (CT) and magnetic resonance imagery (MRI) results at the time of the first hospitalization were reviewed by an experienced pediatric neuro-radiologist. To get an indication of the functioning of each child when discharged from the hospital, a pediatric version of the GOS (Ewing-Cobbs et al., 1999; Miner, Fletcher, & Ewing-Cobbs, 1986; Prasad, Ewing-Cobbs, Swank, & Kramer, 2002) was administered a posteriori. The scale is divided into five levels of functioning. Level 5 is indicative of "good recovery" and corresponds to a return to the child's chronological age or premorbid level of functioning. Level 4, "moderate disability," is assigned if the child (1) presents a significant reduction in cognitive functioning in comparison with his/her premorbid level, (2) presents motor deficits, including hemiparesis affecting daily life activities or (3) has been referred to outpatient rehabilitation services. When the results of cognitive tests are in the deficit range, when severe motor deficits are present, such as loss of postural control or ambulatory ability, or when the child has been referred to an inpatient rehabilitation centre, he/she is rated level 3, "severe disability." The last two levels are "persistent vegetative state" (level 2) and "death" (level 1). Given our pre-determined inclusion criteria, the subjects in our study were likely to score between 3 and 5 on the GOS.

Each of the children in the clinical group was paired with a healthy child based on age, gender, socio-economic status and family composition. The control children were recruited at three schools in the Mauricie-Centre du Québec region of the province. The medical records of children who corresponded to the desired pairing variables had to show no metabolic or neurological disorders, no history of brain injury and a normal pre-, peri- and post-natal history. The control children had to have experienced no academic delays nor showed signs of learning problems.

Birth and demographic pairing data were obtained by examining the medical charts of the children in the SBS group and by having the caretaker of the children in both groups complete a child development questionnaire. Demographic pairing data and birth date appear in Table 1. The two groups were comparable for age at time of assessment [$t(20) = -.234$, $p > .05$], gender ($\chi^2 = .00$; $p > .05$), socioeconomic status ($\chi^2 = .00$; $p > .05$) and family composition ($\chi^2 = .00$; $p > .05$). Mean age of the children at the time of assessment was 7 years and the majority of them were living in a two-parent family with a medium to high income. The boy:girl ratio was 1:1.2 in both groups. Means comparison tests show that the two groups were equivalent for gestational age [$t(20) = -.254$, $p > .05$], birth weight [$t(20) = .926$, $p > .05$] and the 5-minute APGAR scores [$t(20) = .162$, $p > .05$]. An individual examination of the 22 medical charts showed that all the children, including the SBS subjects, were in good medical condition at birth (APGAR > 7 at the three measures). None of the children were considered premature and none weighed less than 2.5 kg at birth.

Procedure

First, verbal consent of each SBS child's caretaker was obtained by the social worker in charge of the case at the time of the study so that a researcher could subsequently contact them by phone regarding the study. The social worker was from a Centre Jeunesse (CJ) (a child protection centre), a physical

Table 1
Demographic and birth informations for the clinical group (SBS) and control group

	Groups	
	SBS ($n = 11$)	Control ($n = 11$)
Demographic variables		
Age at the time of assessment (months)		
M	87.64	90.18
SD	25.52	25.42
Sex		
Girl	6	6
Boy	5	5
Socio-economic status		
Low 5,000$–29,999$	2	2
Medium 30,000$–54,999$	4	4
High >55,000$	5	5
Family composition		
Single-parent	3	3
Two parent	8	8
Foster family	3	0
Neonatal history		
Gestational age (week)		
M	38.18	38.45
SD	2.52	2.5
Birth weight (kg)		
M	3.51	3.21
SD	.83	.69
APGAR scores – 5 minute		
M	9.18	9.09
SD	.60	1.76

rehabilitation centre or a hospital centre in the province of Quebec, depending on each case. Once the caretakers had signed a written consent form allowing the child to participate, they were given an information sheet explaining the study. The study was approved and conducted according to standards set by the research ethics committee of the organizations involved in the project: CHUSJ, the Institut de Réadaptation en Déficience Physique de Québec (IRDPQ) (the Quebec physical rehabilitation institute), the Montreal CJ, and the Université du Québec à Trois-Rivières (UQTR).

Second, once the clinical group was formed, the head researcher contacted three schools that would likely have children who would meet the clinical sample's pairing criteria. The school principals were informed of the nature of the study and were asked to distribute a letter requesting participation to the pupils at their school. Once we had received positive replies, the pairing data was sorted and the parents of matching children were contacted by telephone to explain how the study would work. At the assessment interview, the parents were given an information sheet and they signed a consent form.

For the clinical group, the tests were administered at the hospital or agency in charge of each child's case, when that was possible. Children who lived too far away from these locations were given the tests at

their home. Assessment of the children in the control group took place in their respective school settings. A child development questionnaire was given directly to the children's caretakers or sent home with the children. Each of the assessments lasted a maximum of 2 ½ hour. If a child's condition made it difficult to complete the assessment in one interview, a second appointment was set up for the following week. Once the assessment was complete, a gift worth $10 was given to the child and each caretaker received $10.

The experimenters had at least three years experience in conducting neuropsychological assessments with children. They had attended a 2 hour training session led by the head researcher on administering the battery of tests. Each test score was reviewed by another experimenter, who was blind to the children's group status.

Cognitive measures

A battery of composite tests was developed to assess the children's cognitive functioning. Measures of global and specific functioning were chosen. A short form of the *Stanford-Binet Intelligence Scale*, 4th edition (Thorndike, Hagen, & Sattler, 1986) was chosen as a cognitive measure of the children's global potential. Tests were selected from the *NEPSY* battery (Korkman, Kirk, & Kemp, 2003) to measure attention processes, language and certain specifically frontal-related functions. Mnesic processes were measured with tests from the *Children's Memory Scale* (Cohen, 1997) and visual-motor integration with the *Berry-Buktenica Test* (Beery, 1997). Assessment of frontal functions was completed with the *Maze* test of the *Wechsler Intelligence Scale for Children-III* (Wechsler, 2000) and the *Progressive Figures* test of the *Halstead-Reitan Battery* (Reitan & Wolfson, 1994). The latter test was replaced with the *Trail Making B* test (Reitan & Wolfson, 1992) when the child being assessed was 9 years of age or over.

Statistical analyses

A univariate *t*-test was used to compare the performances of the two groups. The data was processed using SPSS 12.0 for Windows software.

Results

Medical characteristics

The main medical characteristics drawn from the examination of the medical charts of the children in the clinical group are presented in Table 2. On average, the SBS episode took place at the age of 5.09 months ($SD \pm 3.23$). The measure of the state of consciousness at admission (or the lowest score during the first 24 hour of hospitalization) based on the *Glasgow Coma Scale* (GCS) showed that on average the children scored between 11 and 12 out of 15 ($SD \pm 2.79$). Only one child (Case 1) differed from the group, with a GCS score of 5 out of 15; for another child, the score was missing. With the exception of these two cases, all the children obtained scores between 10 and 15 out of 15. SDH was found in 90.9% (10/11) of the cases, extending to the parafacial or interhemispheric area in 70% (7/10), and SAH was present in 45.45% (5/11) of the cases. With the exception of Case 11, SAH was always found in combination with SDH. Nearly three-quarters of the children (72.72%; 8/11) presented with unilateral

Table 2
Medical brain injury-related characteristics of the participants in the study

	Case age at SBS	SDH	SAH	RH	Skull Fx	Other Fx	GCS	GOS
1	1 month	Y	Y	Bilateral	N	N	5	4
2	12 months	Y	N	Bilateral	N	N	12	5
3	7 months	Y	N	N	N	N	13	5
4	6 months	Y	Y	N	N	N	10	5
5	5 months	Y	N	N	N	N	MD	4
6	4 months	Y	N	Unilateral	N	N	12	5
7	2 months	Y	N	Unilateral	N	N	12	4
8	1 month	Y	Y	Bilateral	Y	N	10	5
9	8 months	Y	N	Bilateral	N	N	15	MD
10	5 months	Y	Y	Bilateral	N	N	10	5
11	5 months	N	Y	Bilateral	Y	N	14	4

Note. Y: present; N: absent; SDH: subdural hematoma; SAH: subarachnoid hemorrhage; RH: retinal hemorrhage; Fx: fracture; MD: missing data; GCS: Glasgow Coma Scale; GOS: Glasgow Outcome Scale.

or bilateral retinal hemorrhages described as extensive and multilayered in 70% (6/8). Only two of the children presented with an associated skull fracture. None of the children had a history of lesions acquired prior to the traumatic event. The GOC administered to 10 of the 11 children showed a level of dysfunction ranging from mild to moderate upon their discharge from the hospital.

Neuropsychological measures

The children in the clinical group were assessed at the age of 87.64 months ($SD \pm 25.52$), on average 78.9 months post-trauma; the children in the control group were evaluated at 90.18 months ($SD \pm 25.42$).

The two groups showed significant differences in their intellectual abilities and on other specific functions. Table 3 shows the weighted scores obtained for each of the groups on the short form of the Stanford-Binet test, and the group comparison analyses. A significant difference ($p < .01$) was noted in favor of the control children on the global IQ index. Based on the clinical categories suggested by the test's authors (Thorndike et al., 1986), the children in the clinical group rated, on average, in the low-medium range for global IQ, while the control children were in the medium range.

Table 3 shows that for the attention and memory tests, only certain subscales differentiate the two groups. The *Auditory Attention* test shows a significant difference ($p < .01$) only in part B. A significant difference is noted in the indirect repetition task of the *Digit Span* ($p < .05$) test. Scores for the word list tests do not differentiate the two groups. Scores for learning and differed recall tasks are divergent ($p < .01$ and .05), whereas the children in both groups performed similarly on the recognition task. The visual attention task (*Visual Attention*) and the visual memory task (*Dot Locations*) show no difference between the groups. The NEPSY *Comprehension of Instructions* task and the *Verbal Fluency* tasks involving semantically and phonemically related words differentiate the clinical children from the control children ($p < .01$). However, no significant difference was noted for *Copying Figures*. Significant differences were found on all the tests that called upon frontal functions except for mazes. The *Tower*, *Statue*, and *Knock and Tap* tests all indicated significant differences ($p < .01$ and $p < .001$). The Progressive Figures scores did not vary significantly when one considers the number of errors made.

Table 3
Means, standard deviations and means comparisons for the neuropsychological tests for the two groups

Variables	*M*	*SD*	*t*	*df*	Sig. (2-tailed)
	SBS	Control			
Global IQ[a]	86.36 (15.16)	104.09 (12.10)	−3.03	20	.007
Auditor attention					
Part A[b]	7.45 (3.30)	8.91 (2.02)	−1.25	20	.227
Part B[b]	5.55 (2.77)	8.91 (2.21)	−3.15	20	.005
Visual attention					
Board A[c]	68.64 (22.37)	81.82 (7.83)	−1.84	20	.080
Bord B[c]	58.82 (38.11)	84.55 (7.57)	−2.20	10.79	.057
Digit span					
Forward[b]	7.36 (3.04)	8.09 (2.47)	−.62	20	.545
Backward[b]	7.91 (3.27)	11.00 (3.07)	−2.29	20	.033
Word lists					
Learning[b]	7.55 (3.86)	11.82 (2.40)	−3.12	20	.005
Differed recall[b]	8.82 (3.49)	11.91 (2.51)	−2.39	20	.027
Recognition[b]	9.73 (3.52)	10.18 (3.74)	−.29	20	.772
Dot locations					
Learning[b]	8.73 (3.77)	9.91 (3.91)	−.72	20	.479
Differed recall[b]	9.45 (3.42)	10.55 (2.70)	−.83	20	.416
Comprehension of Instructions[b]	6.73 (2.94)	10.18 (2.04)	−3.21	20	.004
Verbal fluency[b]	7.36 (3.91)	11.27 (2.65)	−2.75	17.59	.013
Copying figures[b]	6.73 (3.35)	9.27 (2.57)	−2.00	20	.059
Mazes[b]	8.45 (4.66)	10.00 (3.98)	−.84	20	.412
Tour[b]	7.82 (3.13)	11.36 (2.66)	−2.87	20	.010
Knock and Tap[c]	11.27 (7.49)	76.50 (4.74)	−24.07	17.08	.000
Progressive Fig/Trail Making B					
Time[d]	136.09 (82.80)	62.00 (36.77)	2.71	13.80	.017
Errors[d]	2.73 (3.04)	1.00 (1.90)	1.60	16.78	.128
Statue	29.27 (27.80)	85.91 (7.01)	−6.55	11.27	.000

[a] Results are presented in weighted scores. Mean IQ is out of 100 ($SD \pm 16$).
[b] Results are shown in standard scores $M = 10$ $SD \pm 3$.
[c] Results are shown in percentiles.
[d] Results are shown in raw scores.

However, a measure of the execution time shows that the clinical children took longer to carry out the task than their healthy counterparts ($p < .05$).

From a clinical point of view, Spreen and Strauss (1998) propose that a score more than one standard deviation below the mean or a rank below the 16th percentile suggests an abnormal index. A score over the 84th percentile indicates an above average result, whereas below the 16th percentile is considered to be below the expected threshold. Results in Table 3 show that all the children are at a normal level, except for the *Auditory Attention* task (Part B) where the result for the children in the clinical group are below normal. The *Comprehension of Instructions*, *Copying Figures* and *Knock and Tap* tests categorize

the children in the clinical group as below normal, although only the *Comprehension of Instructions* and *Knock and Tap* tests show statistical differences ($p < .01$ and .001). The control children are rated as average or high-than-average for these tests. The *Verbal Fluency* test and the *Statue* test show the control group as being clinically above average, whereas the scores of the clinical group are in the normal range.

Discussion

The results of the current study confirm once again the relevance of exploring the cognitive sequelae of SBS a number of years after the trauma. However, it differs from previous studies (Barlow et al., 1999, 2005; Ewing-Cobbs et al., 1998, 1999) in the make-up of its clinical sample. Each of the children selected had to be able to complete the entire evaluation procedure. Children presenting severe neurosensory problems were therefore eliminated. This selection procedure enabled us to go beyond a simple review of medical charts and to measure deficits using standardized tests and avoid encountering floor effects. In such a context, the probability of recruiting children presenting few or no deficits despite their history of non-accidental trauma is greater than in previous studies. However, the procedure enabled us to detect deficits appearing later in the child's development. Results obtained by the team led by Bonnier et al. (1995) have shown that nearly half of victims examined (5/13) went from an apparently normal state of health to abnormality within a period of between 6 months and 5 years. A second assessment may be helpful in eliminating false negative children.

The SBS children show an intellectual performance that is significantly lower than the control children. The children in the clinical group are in the low-average range, whereas the subjects in the control group are in the average range. These initial results corroborate the findings of previous studies that have shed light on the poorer intellectual performance of young children with a history of maltreatment (Cahill, Kaminer, & Johnson, 1999; Elmer & Gregg, 1967; Hoffman-Plotkin & Twentyman, 1984; Morse, Sahler, & Friedman, 1970; Trickett & McBride-Chang, 1995) or, more specifically, inflicted brain injury (Barlow et al., 1999, 2005; Ewing-Cobbs et al., 1998, 1999).

Specific tests provide further evidence of this tendency. First, the children in the clinical group did poorly on verbal tests where complex cognitive functions, such as working memory, or more specifically the central executive (Baddeley, 1986), are called upon simultaneously. The *Auditory Attention* test thus shows group differences because of part B of the exercise that requires the children to select auditory information while processing two instructions in developing their response. This type of task assesses an individual's divided attention (Sohlberg & Mateer, 1989). The process required to maintain and manage multiple instructions is directly related to the efficiency of the central executive (Mazeau, 2003). The two groups differ on their *Digit Span* score because of the reverse recall task. This section of the test requires the child to immediately recall a series of digits in reverse order and is considered a typical measure of working memory (Baddeley, 1986). Another task that primarily requires integrity of the working memory, in the absence of significant language limitations, is the *Comprehension of Instructions* task. The child must retain and process the entire verbal instruction in order to execute the content of that instruction. The children in the clinical group again showed a poorer performance than their healthy peers on this task.

Furthermore, a second group of tests stands out in the means comparison analysis, namely the tasks requiring the children to analyze, think, adjust and inhibit their thinking and behavior. All problem-solving situations call upon these skills in varying degrees. All the tests targeting any of these skills, with the

exception of the mazes, showed differences between the groups. The children in the clinical group thus had greater difficulty generating a large quantity of semantically and phonemically related words, rapidly alternating sequences of forms and efficiently conceiving a mental plan of action in order to reproduce a pattern of counters on an abacus. The *Mazes* test showed no significant differences. Completing mazes requires not only mental planning skills but also visual-motor control and integration abilities. Unlike the *Tower* test, the visual framework provided by mazes minimizes the mental development required for planning the task. Moreover, results on the visual-motor integration task leads us to believe that the skills of the clinical children are similar to their healthy peers in terms of visual-motor control and integration, which also contributes to decreasing the risk of errors by the SBS children. The two mental/behavioral inhibition tests show a significant difference between the two groups. The *Statue* test requires the child to inhibit all behavior during a brief period of time, whereas in the *Knock and Tap* test the child must rapidly alternate certain behaviors, depending on the instruction given. The children in the clinical group performed particularly poorly on these tasks, mainly because of their difficulty in quickly interrupting a behavior. Adding a condition of alternation to the task simply raises the level of difficulty.

Lastly, an examination of the children's mnesic performance raises some additional considerations. Firstly, we observed that once again the difference between the groups is only apparent in the verbal test, specifically the list of words. Secondly, learning and delayed recall (30 minute) scores differ significantly, whereas the recognition score is equivalent for both groups. This is an interesting observation because it shows probable weaknesses in processes for encoding and retrieving information (Tulving, 1983). These results suggest that the children in the clinical group have greater difficulty efficiently organizing and classifying elements of information presented in view of storing them in their long-term memory (LTM). This process relies on the proper functioning of the working memory, but also on mental organization/planning (Baddeley, 1986; Desgrandes, Piolino, Bernard, & Eustache, 2003; Tulving, 1983). The word recognition test demonstrates, however, that the elements of information are stored in sufficient quantity, but given the poor encoding process, word retrieval is more difficult in the absence of forced choices.

In summing up, the children in the clinical group showed significant weaknesses in comparison with their healthy peers for intellectual performance, working memory, shared attention, reasoning, mental organization/planning, mental alternation and inhibition, particularly in verbal mode. Some researchers suggest that these skills should be grouped under the term "executive functions"—functions that are directly linked to the integrity of the frontal lobes (Anderson, Northam, Hendy, & Wrennall, 2001; Lezak, 1995; Shallice, 1990). Our results lead us to conclude that these skills appear to be deficient in SBS victims to the point of apparently having an impact on their global intellectual performance and their ability to memorize.

Our results tend to confirm the findings of three previous studies that used psychometric instruments (Barlow et al., 2005; Ewing-Cobbs et al., 1998, 1999) to assess child NAHI victims. Ewing-Cobbs and colleagues found not only a drop in intellectual performance but regression over time in alertness/attention, tolerance for frustration and ability to adapt to change in a sample of child victims of traumatic brain injury inflicted at a young age (mean age: 9.28 months). The origins of frontal dysfunction thus appear to become established in early childhood and then, as our results suggest, become more specific as the frontal lobes mature, resulting in more complex deficits at school age. Barlow's team of researchers (2005) evaluated 21 child victims of inflicted traumatic brain injury (mean age at assessment: 59 months) using a developmental scale or an intellectual scale, an adaptive behavior scale and several specific cognitive tests. Globally, the results suggested a mean intellectual performance in the slow range with wide disparity in distribution and attention/memory deficits, resulting in specific learning problems in these children. In

addition, results on behaviors scales suggested numerous behavior problems associated with children's lack of self-control (inhibition).

Although interesting tendencies were noted in the means comparison tests, the differences observed in the clinical group in comparison with normative means were relatively small. Of all the tests that showed a significant difference between the SBS children and their healthy counterparts, only a small number of tests (the *Auditory Attention-B*, *Comprehension of Instructions*, *Copying Figures* and *Knock and Tap* tests) showed results below the normal threshold ($\leq$1 standard deviation below the mean). None of them were more than 2 standard deviations below the mean, which would indicate a deficit. The results with the greatest difference in comparison to the mean (≈ -1.5 *SD*) were the *Auditory Attention-B* and *Knock and Tap*, tasks that specifically call upon mental alteration. The children in the clinical group showed concrete differences in comparison with the control group for several functions, but did not display clear-cut deficits in comparison with normative groups on either of the measures used.

Several factors that are intrinsic and extrinsic to children can account for the above results. The reader will recall that the clinical group was constructed based on not only SBS diagnostic criteria, but also on the children's ability to complete the battery of tests. Therefore, none of the children could have an estimated intellectual potential lower than the threshold for moderate deficiency, or could be blind or deaf, and they had to have the functional use of one of their two upper limbs. This particular feature of the present study was included to avoid encountering floor effects that would invalidate the measures, but does decrease the probability of rejecting the null hypothesis. Table 2 shows that nearly all the children in the clinical group presented a partially clouded consciousness upon their arrival at the emergency ward. Only one child scored lower than 9 on the GCS. Typically, a score between 9 and 12–13 with a state of altered consciousness for up to 24 hour is a sign of moderate TBI (Gervais & Dubé, 1999). The majority of the children in our study presented the equivalent of a mild or moderate TBI.

In addition to the fact that the head trauma of our SBS children was less severe than that of samples used in previous studies (Barlow et al., 2005; Ewing-Cobbs et al., 1998, 1999), post-trauma treatment must be taken into account. The majority of the children's caretakers (7/11) reported on the child development questionnaire that their child had been or was still in rehabilitation. Access to rehabilitation services and adapted educational services following TBI are favorable prognostic markers (Sohlberg & Mateer, 1989) in children (Bourque, 1999). Treatment adapted to individual needs may have had a significant impact on test results.

Nevertheless, the persistent deficits revealed in the current study clearly cannot be related to either low family income or family composition. Some studies have shown a relationship between quality of cognitive development and socioeconomic level (Lupien, King, Meaney, & McEwen, 2001; Palacio-Quintin, 1995). Cummings and Davies (1994) demonstrated that parental conflicts can lead to an increased risk of developmental delays in children. The fact that the pairing of the children in the current study was based on family income and family composition, and the absence of contributory variables associated with the children's life history (birth, health) means that we can state with greater certainly that the deficits can be attributed to SBS.

Although the results of the present study are promising, certain limitations must be considered in future studies. The small number of subjects and their neurosensory characteristics significantly limits the generalization of our results. The pre-injury and particularly the post-injury environment (maltreatment, foster family/natural family, global stimulation, attachment) are likely to influence outcome and it is difficult to control for such factors. We only know that none of the children had a history of cerebral lesions previous to the SBS event and that each child had been followed up by youth protection services.

In conclusion, the present study therefore suggests that cognitive dysfunctions primarily associated with frontal regions of the brain were probable in the children in the clinical group years after their SBS trauma. Although the majority of the children were, according to their parents, functioning normally, our study demonstrates the presence of subtle deficits. Moreover, these deficits result in learning problems in school (Bonnier et al., 1995). Further evaluations with MRI or functional imaging techniques would have been of interest and should be considered in future follow up studies. Previous research has shown that the frontal lobes and their associated functions develop right up until the end of adolescence (Anderson & Jacobs, 2004). Thus, all child victims of SBS, even those affected to a lesser degree, will likely have special needs throughout their entire life. Regular monitoring of their cognitive functions during their elementary and high-school years is necessary in order to set up an intervention program designed for the particular needs of each child.

Acknowledgements

The authors would like to thank the CHUSJ, the IRDPQ and the Montreal CJ for their valuable collaboration in this study.

References

Anderson, V., & Jacobs, R. (2004). Front lobe damage in children: Interruptions to normal development. In P. Nolin & J.-P. Laurent (Eds.), *Neuropsychologie cognition et développement de l'enfant* (pp. 83–105). Quebec: Les Presses de l'Université du Québec.

Anderson, V., Northam, E., Hendy, J., & Wrennall, J. (2001). *Developmental neuropsychology*. Philadelphia, PA: Taylor Francis.

Baddeley, A. D. (1986). *Working memory*. London: Oxford University Press.

Barlow, K. M., & Minns, R. A. (2000). Annual incidence of shaken impact syndrome in young children. *The Lancet*, *356*, 1571–1572.

Barlow, K. M., Thompson, E., & Minns, R. A. (1999). Neurological outcome of non-accidental head injury. *European Journal of Paediatric Neurology*, *3*, A139–A140.

Barlow, K. M., Thompson, E., Johnsons, D., & Minns, R. A. (2005). Late neurologic and cognitive sequelae of inflicted traumatic brain injury in infancy. *Pediatrics*, *116*, 174–185.

Beery, K. E. (1997). *The Beery-Buktenica Developmental Test of Visuo-Motor Integration* (4th ed.). Parsippany, NJ: Modern Curriculum Press.

Bonnier, C., Nassogne, M.-C., & Evrad, P. (1995). Outcome and prognosis of whiplash shaken infant syndrome; Late consequences after a symptom-free interval. *Developmental Medicine and Child Neurology*, *37*, 943–956.

Bourque, C. (1999). *Cadre de référence clinique pour l'élaboration de programmes de réadaptation pour la clientèle ayant subi un traumatisme cranio-cérébral-volet enfants-adolescents*. Quebec: Société de l'assurance automobile du Québec.

Brenner, S. L., Fisher, H., & Mann-Gray, S. (1989). Race and the shaken baby syndrome: Experience at one hospital. *Journal of the National Medical Association*, *81*, 183–184.

Caffey, J. (1946). Multiples fractures in the long bones of infants suffering from chronic subdural hematoma. *American Journal of Roentgenology*, *56*, 163–173.

Caffey, J. (1972). On the theory and the practice of shaking infants. Its potential residual effects of permanent brain damage and mental retardation. *American Journal of Diseases of Children*, *124*, 161–169.

Caffey, J. (1974). The whiplash shaken infant syndrome: Manual shaking by the extremities with whiplash-induced intracranial and intraocular bleedings, linked with residual permanent brain damage and mental retardation. *Pediatrics*, *54*, 396–403.

Cahill, L. T., Kaminer, R. K., & Johnson, P. G. (1999). Developmental, cognitive and behavioral sequelae of child abuse. *Child and Adolescent Psychiatric Clinics of North America*, *8*, 827–843.

Cohen, M. J. (1997). *Children's Memory Scale*. San Antonio: Harcourt Brace & Company.
Cummings, E. M., & Davies, P. (1994). *Children and marital conflict: The impact of family dispute and resolution*. New York: The Guilford Press.
Desgrandes, B., Piolino, P., Bernard, F., & Eustache, F. (2003). Imagerie fonctionnelle de la mémoire épisodique. In T. Meulemans, B. Desgranges, S. Adams, & F. Eustache (Eds.), *Évaluation et prise en charge des troubles mnésiques* (pp. 123–140). Marseille: Solal.
Duhaime, A. C., Christian, C., Moss, E., & Seidl, T. (1996). Long-term outcome in infants with the shaking-impact syndrome. *Pediatric Neurosurgery*, *24*, 292–298.
Elmer, E., & Gregg, G. S. (1967). Developmental characteristics of abused children. *Pediatrics*, *40*, 596–602.
Ewing-Cobbs, L., Kramer, L., Prasad, M., Canales, D. N., Louis, P. T., Fletcher, J. M., Vollero, H., Landry, S. H., & Cheung, K. (1998). Neuroimaging, physical, and developmental findings after inflicted and non-inflicted traumatic brain injury in young children. *Pediatrics*, *102*, 300–307.
Ewing-Cobbs, L., Prasad, M., Kramer, L., & Landry, S. (1999). Inflicted traumatic brain injury: relationship of developmental outcome to severity of injury. *Pediatric Neurosurgery*, *31*, 251–258.
Fisher, H., & Allasio, D. (1994). Permanently damaged: Long-term follow-up of shaken babies. *Clinical Pediatrics*, *33*, 696–698.
Gervais, M., & Dubé, S. (1999). *Étude exploratoire des besoins en services offerts à la clientèle traumatisée cranio-cérébrale au Québec*. Québec: Université Laval, Institut de Réadaptation en déficience physique de Québec.
Goldstein, B., Kelly, M. M., Bruton, D., & Cox, C. (1993). Inflicted versus accidental head injury in critically injured children. *Critical Care Medicine*, *21*, 1328–1332.
Guthkelch, A. N. (1971). Infantile subdural haematoma and its relationship to whiplash injuries. *British Medical Journal*, *2*, 430–431.
Haviland, J., & Russell, R. I. R. (1997). Outcome after severe non-accidental head injury. *Archives of Disease in Childhood*, *77*, 504–507.
Health Canada. (2001). *Joint Statement on Shaken Baby Syndrome*. Ottawa: Department of Public Works and Government Services.
Hoffman-Plotkin, D., & Twentyman, C. T. (1984). A multimodal assessment of behavioral and cognitive deficits in abused and neglected preschoolers. *Child Development*, *55*, 794–802.
Jenny, C., Hymel, K. P., Ritzen, A., Reinert, S. E., & Hay, T. C. (1999). Analysis of missed cases of abusive head trauma. *Journal of the American Medical Association*, *281*, 621–626.
King, W. J., & MacKay, M. (2000). *Canadian Collaborative Study of Shaken Impact Syndrome*. Final Report. Children's Hospital of Eastern Ontario. University of Ottawa.
King, W., MacKay, M., & Sirnick, A. (2003). Shaken baby syndrome in Canada: Clinical characteristics and outcomes of hospital cases. *Canadian Medical Association Journal*, *168*, 1–5.
Korkman, M., Kirk, U., & Kemp, S. (2003). *NEPSY: Bilan neuropsychologique de l'enfant*. Paris: Les Éditions du Centre de Psychologie Appliquée.
Lezak, M. D. (1995). *Neuropsychological assessment* (3rd ed.). New York: Oxford University Press.
Ludwig, S., & Warman, M. (1984). Shaken baby syndrome: A review of 20 cases. *Annals of Emergency Medicine*, *13*, 104–107.
Lupien, S. J., King, S., Meaney, M. J., & McEwen, B. S. (2001). Can poverty get under your skin? Basal cortisol levels and cognitive function in children from low and high socioeconomic status. *Development and Psychopathology*, *13*, 653–676.
Mazeau, M. (2003). *Conduite du bilan neuropsychologique chez l'enfant*. Paris: Masson.
Miner, M. E., Fletcher, J. M., & Ewing-Cobbs, L. (1986). Recovery versus outcome after head injury in children. In M. E. Miner & K. A. Wagner (Eds.), *Neural trauma: Treatment, monitoring and rehabilitation issues* (pp. 233–240). Stoneham, MA: Butterworth.
Morse, C. W., Sahler, O. J. Z., & Friedman, S. B. (1970). A three year follow-up study of abused and neglected children. *American Journal of Diseases of Children*, *120*, 439–447.
Palacio-Quintin, E. (1995). Les différences de développement cognitif entre enfants de milieux-socio-économiques différents et les facteurs associés à ce phénomène. In J. Lautrey (Ed.), *Universel et différentiel en psychologie* (pp. 305–325). Paris: PUF.
Prasad, M. R., Ewing-Cobbs, L., Swank, P. R., & Kramer, L. (2002). Predictors of outcome following traumatic brain injury in young children. *Pediatric Neurosurgery*, *36*, 64–74.
Reitan, R. M., & Wolfson, D. (1992). *Neuropsychological evaluation for older children*. Tucson, AZ: Neuropsychology Press.
Reitan, R. M., & Wolfson, D. (1994). *Neuropsychological evaluation of young children*. Tucson, AZ: Neuropsychology Press.

Shallice, T. (1990). *From neuropsychology to mental structure*. New York: Cambridge University Press.

Sinal, S. H., & Ball, M. R. (1987). Head trauma due to child abuse: Serial computerized tomography in diagnosis and management. *Southern Medical Journal*, *80*, 1505–1512.

Sohlberg, M. M., & Mateer, C. (1989). *Introduction to cognitive rehabilitation*. New York: Guilford Press.

Spreen, O., & Strauss, E. (1998). *A compendium of neuropsychological tests*. New York: Oxford University Press.

Thorndike, R. L. Hagen, E. P., & Sattler, J. M. (1986). *Échelle d'intelligence Standford-Binet 4éme édition*. Montréal: Institut de Recherches Psychologiques inc.

Trickett, P. K., & McBride-Chang, C. (1995). The developmental impact of different forms of child abuse and neglect. *Developmental Review*, *15*, 311–337.

Trocmé, N., MacLaurin, B., Fallon, B., Daciuk, J., Billingsley, D., Tourigny, M., Mayer, M., Wright, J., Barter, K., Burford, G., Hornick, J., Sullivan, R., & MacKenzie, B. (2001). *Canadian incidence study on reported child abuse and neglect: Final report*. Ottawa: Department of Public Works and Government Services.

Tulving, E. (1983). *Elements of episodic memory*. London: Oxford University Press.

Wechsler, D. (2000). *Wechsler Intelligence Scale for Children, French-Canadian adaptation* (3rd ed.). Toronto: Harcourt Canada Assessment Company.