Long Term
Behavioural, Psychiatric and Cognitive Outcomes
Following
Mild Head Injury in Childhood

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Abstract

Mild head injury is generally considered to be a common but benign childhood event. Previous studies investigating potential cognitive and behavioural consequences have produced mixed findings and controversial outcomes, in part due to a number of methodological difficulties. The present study used a longitudinal birth cohort (initiated in 1977) which permitted the use of a fully prospective design. Of the total original cohort of 1265 children, 134 sought medical attention for a mild head injury with confirmed or suspected concussion occurring between birth and ten years of age. The children were grouped into those who received medical attention at an outpatient facility (n = 96) and those who were hospitalised overnight for observation (n = 36). The remainder of the cohort acted as a reference group against which outcomes for the head injured groups were compared. After controlling for a wide range of demographic, family and pre-injury characteristics, the mild head injury inpatient group but not the outpatient group displayed increased attentional and conduct difficulties, as rated by mothers and teachers. These difficulties were evident over 7-13 years in the inpatient subgroup who experienced an injury between 0-5 years and over 10-13 years in the complete inpatient sample. Similar trends were evident in the 6-10 year inpatient subgroup but these findings failed to reach significance. In terms of psychiatric outcomes (DSM-III-R) evaluated when the children were between 14 and 16 years, significant head injury status effects were found for conduct disorder and substance abuse for children in the 0-5 year olds. When analysed according to severity, increased problems were evident for the 0-10 inpatient group on measures of substance abuse, the 0-5 inpatient group on substance abuse ADHD, and CD/ODD, and mood disorders in the the 6-10 outpatient group. These findings strongly suggest that mild head injury in childhood may produce long term adverse outcomes. Therefore, it seems premature to regard all mild head injuries as a benign childhood event.

Long Term Behavioural, Psychiatric and Cognitive Outcomes Following Mild Head Injury in Childhood.

1.1 General Introduction

1.1.1 Overview

Mild head injury is one of the most frequently occurring injuries during childhood (King, 1991; Kraus, 1995). Any residual deficits from mild head injury that may effect educational or social function and development will thus be of immense importance in terms of the total number of individuals affected. Increased awareness of this important issue has escalated research on mild head injury in childhood in an effort to define the deficits and potential long-term outcomes associated this type of injury (see Satz et al., 1997 for a review; and Table 1 for an update, pp. 7 to 27; note, Table 1 is also provided for ease of reference in loose form in the appendix) As is apparent from Table 1, the results regarding outcomes of mild head injury in childhood have been mixed, they have also generated considerable controversy. Some studies report that children may suffer a number of difficulties following mild head injury including deficits in attention, hyperactivity, behaviour problems, reading deficits and difficulties with new learning (e.g., Andrews, Rose & Johnson, 1998; Asarnow, Satz, Light, Lewis & Neumann, 1991; Barnes, Dennis & Wilkinson, 1999; Bijur, Haslum & Golding, 1990; Gulbrandsen, 1984). Other studies have failed to find adverse outcomes after mild head injury in children (e.g., Asarnow et al., 1995; Chadwick, Rutter, Brown, Shaffer & Traub, 1981; Fletcher, Ewing-Cobbs, Miner, Levin & Eisenberg, 1990; Ponsford et al., 1999; Prior, Kinsella, Sawyer, Bryan & Anderson, 1994).

These mixed outcomes may be related to one of several methodological problems that often characterise research in this area. Perhaps the most obvious difficulty in this literature is the lack of longitudinal research, with few studies extending beyond five years post-injury. Table 1 provides a summary of the field from the perspective of the different methodologies used and focuses, in particular, on the duration of post-injury follow up. The Table shows that there is little information regarding the possible long term outcomes of what may initially appear to be subtle or transient deficits. Another key problem is that the majority of studies rely on retrospective information regarding the premorbid functioning of the child and family. The present study addressed these two shortcomings by using data collected from a large longitudinal cohort who constituted the Christchurch Child Development Study of 1265 children born during mid 1977 in the urban region of Christchurch in the South Island of New Zealand. Information on these children has been gathered prospectively on a regular basis since birth. This longitudinal study also enables comparisons of information on non-injury characteristics in children with and without reported injury to take into account the potential confounds that those characteristics may have on the apparent outcomes of early mild head injury. Another advantage of this type of cohort is that it reflects a more representative sample than is apparent in nearly all published studies of mild head injury, as it provides an unbiased and broad non-injured reference group and all the children in this study who were reported to have experienced a mild head injury were available for analysis. In contrast, most studies only have available an opportunistic sample of subjects who present to an outpatient facility, or have been admitted to a hospital.

1.1.2 Epidemiology

It is estimated that around 100 000 new cases of childhood head injury will be reported in the U.S. each year (Kraus, Fife & Conroy, 1987), which corresponds to around 1000 cases each year in New Zealand, consistent with the overall New Zealand population estimate of about 9000 cases per year (Carr, 1993). Estimates vary depending on whether they are derived from hospital admissions or discharge information, on admission criteria, and on how ‘childhood’ is defined. In a review of research published in the last 20 years, Kraus (1995) reported an average incidence of head injury of 180 per 100 000 per year in children under 15 years of age. This rate was calculated on children admitted to hospital with a confirmed diagnosis of head injury. Approximately 90% of childhood head injuries are classified as mild (Goldstein & Levin, 1987; Kraus et al., 1987; Kraus, Fife, Cox, Ramstein & Conroy, 1986).

Figures for childhood head injury are increased substantially over those based on hospital admissions when it is calculated that around three to five times as many will be seen either by their GP or at the accident and emergency department and sent home without being admitted (Jennett & MacMillan, 1981; Wrightson, 1994; Wrightson & Gronwall, 1998). Even apart from cases that are referred for any kind of medical evaluation, it is likely that a number of other factors may lead to under reporting of childhood head injury. For example, falls and recreational activities account for the vast majority of paediatric head injury, yet these injuries are often unobserved and the child may not report them to an adult (Kraus, et al., 1986). Further, when injuries are observed, children rely on parents to recognise the event as requiring medical care and to present them for treatment. Also, as children are in the care of adults who can supervise their recovery, there may be a tendency to send them home whereas an adult would have been admitted to hospital (Segalowitz & Lawson, 1995). Segalowitz & Lawson (1995) suggest that only a 3% recorded prevalence of head injuries, cumulative to 15 years, is identified through hospital admissions. This prevalence rate differs markedly from that reported by research using the self report method which has consistently identified over ten times this rate (Segalowitz & Brown, 1991; Crovitz, Horn & Daniel, 1983; Body & Leathem, 1996).

Gender differences appear to be a relatively stable feature of head injury, with boys being more likely to suffer a head injury than girls. According to Kraus (1995), head injury is 2.2 times more common in males between the ages of 5 and 14. Hours of exposure to high risk activities, rather than gender, may account for much of the observed differences (Rivara, Bergman, LoGerfo & Weiss, 1982).

1.1.3 Cause of Injury

Although type of injury varies according to the age of the child, severe injuries are frequently the result of motor vehicle accidents, whereas mild head injuries are most commonly a consequence of falls, sporting activities and cycling accidents (Gafford, Silva & Langley, 1996; King, 1991; Kraus, Rock & Hemyari, 1990). Mild head injury is usually a low velocity event involving impact of a moving head with a stationary object resulting in an acceleration-deceleration type injury (Yeates, 2000). While it is apparent that mild head injury is a frequent event during childhood, it is often dismissed as trivial as medical intervention is rarely required and alterations of consciousness are mostly transient. The importance of potential problems posed by even mild head injury, however, are highlighted by findings based on modern imaging techniques and animal studies which reveal that such events may result in structural changes to the brain (Jane, Steward, & Gennarelli, 1985; Levin, Williams, Eisenberg, High & Guinto, 1992; Levi, Guilburd, Lemberger, Soustiel & Feinsod, 1990; Povlishock, Becker, Cheng & Vaughan, 1983; Tellier et al., 1999).

1.1.4 Neuropathological correlates

Axonal damage has been acknowledged as a consistent feature of mild head injury. This damage is commonly identified as small lesions in axonal pathways at the junction of the grey and white matter, termed diffuse axonal injury. Diffuse axonal injury occurs across a range of brain sites but is more likely to be located in the brain stem and in subcortical structures that have significant projections to the frontal and temporal lobes. These large calibre, long tract axons, which originate in the brain stem and extend into the cortex and basal ganglia, are thought to be particularly vulnerable to damage (Jane et al., 1985; Levin et al., 1992; Levi et al., 1990; Oppenheimer, 1968). Damage to the frontal lobes and their diffuse connections may be particularly relevant as disruption here is associated with a broad range of cognitive problems, including difficulties in attention, behaviour regulation, planning and organisational skills (Fuster, 1999; Schnider & Gutbrod, 1999).

1.2 Overview of the effects of mild head injury in adults and children.

Much of the research on mild head injury has focused on adults. In general, mild head injury in adulthood is associated with certain characteristic impairments (Zasler, 1993). These include complaints of headaches, difficulties with memory and concentration, sensitivity to light and noise, fatigue and dizziness. Collectively, these symptoms are termed the post concussion syndrome (Bohnen, Jollies, Twijnstra, Mellink & Wijnen, 1995; Gronwall, 1991; Leininger, Gramling, Farrell, Kreutzer & Peck, 1990; Szymanski & Linn, 1992). Although most effects of post concussion syndrome appear to diminish or resolve within three months, there is a minority of individuals who continue to experience problems for varying periods of time (Gronwall, 1991; Leininger et al., 1990). A recent meta-analytic review of neuropsychological studies by Binder, Ruhling and Larrabee (1997) provided support for the view that mild head injury in adults results in continuing problems for some individuals. Binder et al. (1997) reported a small but detectable association between mild head injury in adults and continuing cognitive deficits, with attention/ concentration and memory being most effected ($d = 0.20$, $p < 0.006$ and $d = 0.19$, $p < 0.06$, respectively).

However, the recovery pattern seen in adults cannot be considered as analogous to that of children. Multiple measures of premorbid functioning are usually available for adults and recovery is generally conceptualised as a return to premorbid functioning. By contrast, with children there is commonly little premorbid information, making measurement of recovery difficult. Further, children are in the most active period of developmental change, and a head injury may disrupt this process. In contrast to characteristic outcomes for adults, as indicated, the findings for mild head injury in children have been more variable. Research suggests that recovery will be less complete in children than adolescents, therefore, this review will focus on children injured prior to age 14 (Taylor & Alden, 1997). A detailed review of publications produced between 1975 and 1995 was recently provided by Satz et al., (1997). Table 1 (pp. 7-27) provides a revised summary of studies on mild head injury in children produced between 1975 and 2000. This table is organised according to the main methodological characteristics of the study, particularly the maximum duration of follow up, together with the reported outcomes. The next section (1.2.2) evaluates key issues in this research; italicised numbers after each reference cited below correspond to the numbering on Table 1. To further assist the reader, studies cited are also listed in terms of outcomes in Table 2.

1.3 Review of research on outcomes following mild head injury

1.3.1 Cognitive Outcomes

The term cognition is used to refer to a wide range of mental activities including perception, attention, memory processes, language, problem solving and reasoning. As can be seen in Table 1, by far the majority of studies to date have focused on aspects of cognition as a possible outcome following mild head injury in children. Of these studies, 17 have reported adverse outcomes following mild head injury and 24 have reported no evidence of deficit (Table 2). A variety of neuropsychological tests have been used to capture possible deficits in cognition following mild head injury in children including tests of arithmetic and spelling (Ewing-Cobbs et al., 1998: *18*) language (Ewing-Cobbs, Levin, Fletcher, Miner & Eisenberg, 1989: *37*; Ewing-Cobbs, Levin, Eisenberg & Fletcher, 1987: *38*; Chapman et al., 1992: *16*; Jordan, Oxanne & Murdoch, 1990: *43*; Jordan, Cannon & Murdoch, 1992: *6*), planning (Pentland, Todd & Anderson, 1998: *28*; Levin et al., 1994: *47*), attention (Dennis, Wilkinson, Koski & Humphreys, 1995: *17*), reading (Wrightson, McGinn & Gronwall, 1995: *31*) and memory (Hannay & Levin, 1989: *42*). Given the diversity of measures and the deficits tested, it is not surprising that results regarding cognitive outcomes have been inconsistent.

General Neuropsychological Tests

The most commonly used measures of cognitive ability are general intelligence tests such as the Wechsler Intelligence Scale for Children Revised (WISC-R) or general neuropsychological test battery (Table 1). Six studies have reported adverse outcomes using neuropsychological test batteries (Bassett & Slater, 1990: *33*; Gulbrandsen, 1984: *41*; Klonoff, Low & Clark, 1977: *20*; Levin & Eisenberg 1979a: *49*; Levin & Eisenberg, 1979b: *21*; Lyons & Matheny, 1984: *23*), while 14 have reported no evidence of deficits (Asarnow et al., 1995: *32*; Bawden, Knight & Winogron, 1985: *34*; Bijur, 1990: *11*; Butterbaugh, Roochvarg, Slater-Rusonis, Miranda & Heald, 1993: *14*; Costeff et al., 1988: *3*; Chadwick et al., 1981: *15*; Godfrey, 1999: *4*; Knights et al., 1991: *45*; Papero, Prigatano, Snyder & Johnson, 1993: *27*; Ponsford et al., 1999: *53*; Prior et al., 1994: *54*; Leahy, Holland & Frattalli, 1987: *46*; Leathem & Body, 1997: *60*; Winogron, Knights & Bawden,

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Study	Head injury definition	Design	Source of participants	Preinjury factors	Non head injured control group(s)	Follow-up(s)	Type of assessment	Reported outcome
Maximum period of follow up after head injury of greater than 10 years								
[1]§ Klonoff et al. (1993)	*Mild* (*n* = approx. 90% Cross-sectional of 159): not defined, based on length of consciousness, skull fractures, EEG ratings. and post traumatic seizures	Longitudinal	Consecutive admissions to hospitals	Statistically controlled	No	Interviewed 159 of the original sample of 231, 23 years post injury	Standardised interview	Adverse: Subjective sequelae in physical, intellectual or emotional domains were reported as due to the head injury by 31% of the sample. These sequelae were reported to be related to the severity of the original injury and initial IQ. The results for this study are reported for the group as a whole making it difficult to distinguish outcomes for different level of severity.
Maximum period of follow up after head injury 5 - 10 years								
[2]‡ Colantonio et al. (1998)	*Mild* (*n* = 24): GCS 13-14 & 15 with LOC or loss of memory of events immediately prior to accident or altered mental state and confirmed by CT or MRI if available *Mild -Mod*: (*n* = 27) *Moderate*: (*n* = 7) GCS 9-12 *Severe*: (*n* = 20) GCS < 9 *Age*: 15-19 yrs	Retrospective	Record review of onsecutive admissions to a large tertiary care facility from October 1988 - March 1989	Not considered	No, nomative data used as a control group	T1: 5 yr or more post injury. Administerd by phone for 47 subjects and through an informant for 4 subjects who were unable to use a phone to communicate	Standardised Quality of Life (QoL) measure: MOS-SF36, Head Injury Symptom Checklist, CIQ,	Adverse: Lower scores than normative data on all QoL measures except pain with the gratest concern for both mild and severe HI subjects being mental health. Mild HI subjects reported as many or more QoL symptoms in the previous 4 wks compared to mod-severe HI, posibly due to better insight. It was noted that lower home integration scores as measured by the CIQ for some HI subjects may not acurately reflect their true integration status as they my be living at home or may not be expected to do home tasks even though they are able.
[3] Costeff et al. (1988)	*Mild* (*n* = 23): hospitalised in local paediatric ward after head trauma *Severe* (*n* = 12): hospitalised on a neurosurgical unit (Follow-up assessment was performed in unselected samples from a larger cohort presented in Horowitz et al. (1983)	Retrospective	Previous admissions to emergency room	Not considered	No	T1: 3.5 - 10.0 yr follow up	Neuropsychological: Bender-Gestalt Copying. Test, Benton Visual Retention Test, and four WISC-R sub tests	Null: Although these results did not show any impairment in the mild group, the results were weakened by the small and potentially biased samples at follow up as well as by the limited assessment battery used., it is unclear what the basis was for follow up and whether it was the same for each group

Study	Head injury definition	Design	Source of participants	Preinjury factors	Non head injured control group(s)	Follow-up(s)	Type of assessment	Reported outcome
[4]‡ Godfrey (2000)	*Mild* (*n* = 38): Evidence of blow to head and medical intervention sought and either 2 or more concussion symptoms or injury described as concussion or suspected concussion. Hospitalised < 24 hr	Longitudinal	Dunedin Multi-Disciplinary Health & Development Study	Exclusion criteria: Hx neurological abnormality, Hx of HI, pre injury characteristics statistically controlled	Other injury & No injury controls	T1: 3 yr pre injury T2: 5 yr pre injury T3: 7 yr pre injury T4: 1-6 yr after injury	Teacher & Parent Child Behaviour questionnaire, WISC-R, Rey Osterreith Complex Figure Test, RAVLT, Trail-Making Test, Grooved Pegboard, WSC, Verbal Fluency Test	Null: Neuropsychological measures: no deficits reported on any neuropsychological testing. Apart from significantly more males in the MHI groups, children did not significantly different from children with fractures or children with no injuries on any family or personal premorbid variables. Psychosocial: no difference between the groups on post post injury behaviour as rated by parents and teachers.
[5] Horowitz et al. (1983)	*Mild* (*n* = 154): at local paediatric hospitalisation with a head injury *Severe* (*n* = 26): required neurosurgical hospitalisation *Ages:* 0-7 at injury; 50% of 370 cases (original sample) were available for follow-up	Retrospective	Chart review of hospital patients	Not considered	No	T1: 4-10 yr post injury	Psychosocial: telephone survey focused on physical symptoms, school adjustments, and placement	Adverse (mild): Results showed an elevated rate of symptoms (headaches, dizzy spells, and bed wetting) and school adjustment problems; only 63% of the mild group were in the normal range for scholastic progress; inadequacies of case definition, lack of controls for preinjury risk factors or post injury non injured comparisons, and subjective assessment method weakened results
[6] Jordan et al. (1992)	*Mild* (*n* = 14): GCS > 8 (but 93% had GCS 13) at injury: *Age*: 5-13 yr	Cross-sectional	Previous admissions to paediatric hospital	Exclusion criteria: presence of intellectual handicap, neurological disease, or speech-language impairment prior to the injury	Yes (n = 14)	T1: 10 yr post injury	Neuropsychological (language): TOAL-2. NCCEA, and BNT	Null: No differences on any of the language measures between the mild and other-injury group: results do not address the effect of MHI on more comprehensive language measures during the first yr post injury
[7] Kewman et at. (1992)	*Mild* (*n* = 21): GCS 13-15 *Moderate* (*n* = 10): GCS 9-12 *Severe* (*n* = 21): GCS <9	Cross-sectional	Neuropsychology service	Exclusion criteria: previous brain insult or organicity	No	T1: 1-72 mo post insult	Neuropsychological: WISC-R Academic: WRAT-R	Indeterminate*

Study	Head injury definition	Design	Source of participants	Preinjury factors	Non head injured control group(s)	Follow-up(s)	Type of assessment	Reported outcome
Maximum period of follow up after head injury 1 - 5 years								
[8]‡ Andrews et al. (1998)	*Mild* (*n* = 8):LOC < 20 mins. GCS 13-15 and PTA ≤ 1 hr. *Moderate*(*n* = 9): LOC greater than 20 mins, GCS 9-12, PTA < 1 day. *Severe*(*n* = 10): LOC greater than 24 hr, GCS < 8 and PTA > 7 days. *Age*: 6.6-17.8y	Cross sectional	Hospital admissions	Hx of previous HI or neurological insult, evidence of abuse or neglect, psychological disorder, LD & any other developmental disorder	Yes (matched for sex, age and SES to 27 children recruited from local schools)	T1: > 6 mo, mean T# of 1.4 yr (mild) to 1.5 yr (severe)	Semi-structured interview with child & caregiver Behavioural assessment: VABS, DeBlois aggressive and antisocial Behaviour Scale Coopersmith Self Esteem Inventory Children's Loneliness Scale.	Adverse findings: HI children showed significantly lower levels of self esteem and adaptive behaviour, and higher levels of loneliness, maladaptive behaviour and aggressive/antisocial behaviour. Weakness, no consideration of preinjury characteristics & small sample size.
[9]§ Asarnow et al. (1991)	*Mild* (*n* = 10): PTA < 4 hr, no coma or only transient LOC *Age*: mean 7.6 yr *Severe* (*n* = 11): LOC > 9 days *Age*: mean 6.9 yr	Retrospective	Outpatient paediatric treatment centre	Exclusion criteria: Hx of CNS insult or disease, development delay, or behavioural problems	No	T1: at least 1 yr post accident; M = 3.7 yr for the mild and 2.2 yr for the severe groups	Psychosocial: CBCL and VABS	Adverse (mild): showed excessive rate of behaviour problems only on the CBCL; results should be viewed with caution, given the small sample sizes and the absence of an other-injury control group to ensure that the behaviour problems were specific to head injury; Asarnow et al. (1995) have recently suggested that recruitment of mild cases from a rehabilitation hospital may have biased the selection toward more moderate injuries
[10]‡ Barnes et al. (1999)	*CHI* of sufficient severity to warrant hospital admission (*n* = 55): (40% GCS of 13-15 and 40% GCS < 8). *Age*: 1 yr 4 mo -15 yr 8 mo	Cross-sectional	Recruited from hospital database	Exclusions: HI as a result of abuse, Hx of developmental delay or academic, emotional or attentional difficulties	No	T1: 7 mo - 9 yr 9 mo after injury, mean 3 yr	Word Identification and Passage Comprehension from the Woodcock Reading Mastery Test-Revised.	Adverse: Difficulties with word decoding and reading comprehension skills. Age effects: Children differentially affected depending on age at injury. Children < 6.5 yr most at risk for difficulties in acquiring reading decoding skills. Weaknesses of the study includes wide variation between injury and time of testing and range of HI severity.

Table 1. *(continued)* **Methodological Characteristics of Studies of MHI in Children and Adolescents (1970–2000)**

Study	Head injury definition	Design	Source of participants	Preinjury factors	Non head injured control group(s)	Follow-up(s)	Type of assessment	Reported outcome
[11]§ Bijur et at. (1990)	*Mild*: (*n* = 114): ICD-9 code of concussion or LOC and no more than 1 night of hospitalisation *Age*: 5-10 yr	Prospective	Sub sample of a 1970 British birth cohort	Statistically controlled: Scores (at Age 10) were adjusted for intelligence, aggressive and hyperactive behaviour; at Age 5, gender, socioeconomic status. and six additional social factors	Yes (design included participants with no injury, n = 1,374), bums (n = 107), fractures (n = 466), and lacerations (n 504)	T1: Age 5 (prior to the index injury) T2: Age 10 (I-5) yr post injury)	Neuropsychological: British Ability Scale, mathematics. and reading Psychosocial: Rutter Child Behaviour Questionnaire and Conner's Parental Questionnaire	Neuropsychosocial: No differences between the MHI and no-injury group was found when adjustments were made for potential pre-accident risk factors; however, the battery did not include more sensitive measures (e.g., tests of sustained and divided attention and psychomotor speed) Academic: No differences between groups in math or reading ability after the scores were adjusted for prior risk factors Psychosocial: After parents' and teacher's ratings were adjusted for prior risk factors, the teacher's rating of hyperactivity was .4 SD higher than the M of the other-injury groups
[12] Black et al. (1970)	Only children suffering LOC, skull fractures, or neurological effects were included; severity was not subdivided	Prospective	Consecutive admissions to hospital	Statistically controlled	No	T1: during hospital admission T2: 3 mo T3: 1 yr T4: 2 yr T5: 3 yr T6: 4 yr T7: 5 yr	Neuropsychological: WISC Psychosocial: looked for signs of post traumatic syndrome	Indeterminate*
[13]§ Brown et al. (1981)	*Mild* (*n* = 29): PTA > 1 hr and < 1 wk *Severe* (*n* = 31): PTA ≥ 7 days *Age*: 5-14 yr	Prospective	Hospital admissions	Controls "closely comparable" on attributes expected to relate to preinjury intellectual and scholastic ability	No matched controls for the mild group	T1: recovery from PTA T2: 4 mo T3: 1 yr T4: 2.25 yr post injury	Neuropsychological: WISC, Paired Associate Learning. Object Naming. Verbal Fluency, Continuous Performance Test, Stroop test, Matching Familiar Figures (mild cases were given more limited testing, only six sub tests from the WISC) Academic: Neale Analysis of Reading Ability	Null Neuropsychological: Mild group showed lower WISC PIQ (vs. controls for severe group) at each follow-up assessment, with virtually no recovery; they concluded that the effects of the MHI was negligible and largely due to pre-accident risk factors, including low IQ; however, results should be viewed with caution due to the lack of a matched control group for the mild group and the use of only WISC sub tests, which may be too brief and global a measure to be sensitive to changes in attention, memory, and psychomotor speed Academic: Approximately 40% of the mild group showed a high rate of reading backwardness throughout the duration of the follow-up; they concluded that a lack of recovery pattern precluded attributing poor performances on the reading test to the effects of the head injury; however, use of a more rigorous selection method that controls for preinjury risk factors in each injury group and control groups for each injury severity level would strengthen results

Study	Head injury definition	Design	Source of participants	Preinjury factors	Non head injured control group(s)	Follow-up(s)	Type of assessment	Reported outcome
[14] Butterbaugh et al. (1993).	*Mild-mod* (*n* = 13): GCS > 8 (M 13.9) *Severe* (*n* = 9): GCS 3-8	Prospective	Trauma centre	Exclusion criteria: Hx of retardation or neurological disorders	Yes (n = 25)	T1: 1 mo post injury T2: 18 mo post injury	Neuropsychological: WISC-R or WAIS-R Academic: WRAT-R and GORT	Null: Mild CHI was pooled with moderate CHI group for analysis; initial effect at 1 mo between mild-mod and control group on 24 tests (F1Q and PIQ), which disappeared at 18 mo; difference not clinically significant (initial mild-mod: PIQ = 96, F1Q = 98)
[15]§ Chadwick et al. (1981)	*Mild* (*n* = 29): PTA > 1 hr and < 1 wk *Severe* (*n* = 31): PTA ≥ 7 days *Age*: 5-14 yr	Prospective	Hospital admissions	Controls "closely comparable" on attributes expected to relate to preinjury intellectual and scholastic ability	No matched controls for the mild group	T1: recovery from PTA T2: 4 mo T3: 1 yr T4: 2.25 yr post injury	Neuropsychological: WISC, Paired Associate Learning. Object Naming. Verbal Fluency, Continuous Performance Test, Stroop test, Matching Familiar Figures (mild cases were given more limited testing, only six sub tests from the WISC) Academic: Neale Analysis of Reading Ability	Null Neuropsychological: Mild group showed lower WISC PIQ (vs. controls for severe group) at each follow-up assessment, with virtually no recovery; they concluded that the effects of the MHI was negligible and largely due to pre-accident risk factors, including low IQ; however, results should be viewed with caution due to the lack of a matched control group for the mild group and the use of only WISC sub tests, which may be too brief and global a measure to be sensitive to changes in attention, memory, and psychomotor speed Academic: Approximately 40% of the mild group showed a high rate of reading backwardness throughout the duration of the follow-up; they concluded that a lack of recovery pattern precluded attributing poor performances on the reading test to the effects of the head injury; however, use of a more rigorous selection method that controls for preinjury risk factors in each injury group and control groups for each injury severity level would strengthen results
[16] Chapman et al. (1992)	*Mild-mod* (*n* = 10: GCS > 8 (7 had GCS ≥ 13 but were pooled with others) *Severe* (*n* = 9): GCS ≤ 8	Cross-sectional	Consecutive admissions to neurosurgery service in hospitals	Exclusion criteria: no prior diagnosis of LD or other neuropsychiatric disorder and no evidence of child abuse	Yes (n = 20)	T1: 1-5 yr post injury	Neuropsychological: focused on language, including narrative discourse, vocabulary sub test (WISC-R), and the CVLT	Null: Mild-mod group did not differ the control group

Study	Head injury definition	Design	Source of participants	Preinjury factors	Non head injured control group(s)	Follow-up(s)	Type of assessment	Reported outcome
[17]‡ Dennis et al. (1995)	*CHI* of sufficient severity to warrant hospital admission. GCS 3-15	Cross-sectional	Hospital admissions	Not considered	No	Average 3.5 yr	WISC and GDS (used to generate a number of attentional tasks).	Adverse: HI sample showed poor selective and focused attention in relation to age norms. Only 3.8% of head injured children rated as having intact attentional skills. Age effect: younger group tended to perform more poorly in relation to age norms on selective attention tasks than older group. The study was weakened by presentation of the outcome information for HI group as a whole and there was a lack of control for preinjury factors.
[18]‡ Ewing-Cobbs et al. (1998)	*Mild-Mod*(n = 28): impaired consciousness < 24 hr. *Severe* (n = 33): impaired consciousness ≥ 24 hr *Age*: 5-15 yr	Longitudinal	Hospital admissions	Exclusion criteria: no Hx of HI, no indication of developmental delay or learning disabilities	No	T1: after PTA, average 21 days T2: 6 mo T3: 12 mo T4: 24 mo	Peabody Individual Achievement Test; 3 sub tests of WRAT; spelling, word recognition, arithmetic	Null: Study was designed to compare HI outcomes for different levels of severity. Children with severe injuries had significantly lower academic scores compared to the mild and moderate group at baseline. This improved by 6 mo follow up.
[19]‡ Kinsella et al. (1999)	*Mild* (n = 29): LOC less than 20 min, GCS ≥ 13 without subsequent deterioration, no focal neurological deficits (by CT) *Moderate* (n = 10): GCS 9-12 without subsequent deterioration or a higher GCS with evidence of neurological deficit or CT abnormality Severe (n = 12): GCS of ≤ 8 on admission or within the first 24 hr *Age*: 5-15 yr	Longitudinal	Consecutive hospital admission	No previous Hx of head injury, no neurological disorder or psychiatric dysfunction	No	T1: 3mo T2: 1yr T3: 2yr	CBCL, general health questionnaire, Family Assessment Device	Null: Children with mild & moderate HI did not show a greater incidence of behavioural problems. Severe injury was associated with a greater incidence of behaviour problems. Coping sources of the family were predictive of child's outcome.

Study	Head injury definition	Design	Source of participants	Preinjury factors	Non head injured control group(s)	Follow-up(s)	Type of assessment	Reported outcome
[20]§ Klonoff et al. (1977)	*Minor*: suspected but unproved LOC and no concussion *Mild*: suspected but unproven LOC and concussion *Moderate*: LOC < 5 min and concussion *Severe*: LOC 5-30 min and concussion or skull fractures *Serious*: LOC > 30 min and skull fractures or other sequelae *Age*: (n = 131 ≤ Age 9), (n = 100 > Age 9)	Prospective	Consecutive admissions to hospital	Not considered	Yes	T1: during hospital admission T2: 1 yr T3: 2 yr T4: 3 yr T5: 4 yr T6: 5 yr	Neuropsychological: Reitan-Indiana, WISC-R, and Stanford-Binet Academic: school placement	Adverse: At initial follow up differences were evident between HI groups and controls on 28 of the possible 32 neuropsychological variables for the younger group and 42 out of 48 for the older group. 23% of the children still showed residual impairment on neuropsychological test at the 5 year follow up. Results weakened by presentation of results for the HI group as a whole making in impossible to distinguish outcome for different levels of severity.
[21] Levin & Eisenberg (1979b)	*Grade 1* (n = 23): conscious on admittance, only momentary LOC, no neurological deficits *Grade 2* (n = 7): LOC <24 hr or neurological deficit *Grade 3* (n = 15): LOC > 24 hr	Cross-sectional	Neurosurgical service in hospital	Exclusion criteria: Hx of neuropsychiatric disorder or inability to cooperate with the neuropsychological assessment	No	T1: Grade 1 *Mdn* 28 days (2 - 1,157); Grade 2 *Mdn* 22 days (1 - 440)	Neuropsychological: WISC-R, aphasia screening, visuospatial and visiomotor abilities, memory (Bushke), and somatosensory perception	Adverse (mild): a small number of outliers (typically 7- 10%) on tests; no information about whether these proportions exceeded those expected for each test's normative group; without a non injured control group and a follow-up assessment, it is difficult to determine whether initial effect existed and whether it remitted over time
[22] Lundar & Nestvold (1985)	*Mild* (n = 118): PTA < 24 hr, Ages 1 -19 *Severe* (n = 8): PTA > 24 hr	Prospective	Patients with a head injury as a result of a traffic accident	Not considered	No	T1: 3 mo T2: 1 yr T3: 5 yr	Academic-psychosocial: Parents were questioned about complaints, school performances, and seizures	Adverse: Results showed owed that the rate of children and adolescents without any subjective complaints improved with time, being 35%, 61%, and 75% at 3 mo, 12 mo, and 5 yr, respectively; however, approximately 25% continued to report complaints 5 yr later in this predominantly mild sample Age effect: Younger children were judged to have fewer complaints and a more rapid recovery in the first 3 mo

Study	Head injury definition	Design	Source of participants	Preinjury factors	Non head injured control group(s)	Follow-up(s)	Type of assessment	Reported outcome
[23]§ Lyons & Matheny (1984)	Cotwin method, largely unselected, predominantly mild cases (non compound skull fractures); 10/13 twins were unconscious for 1 hr and hospitalised for ≤ 1 day, 2 were unconscious for 1 hr and hospitalised for 2 days, and 1 twin was unconscious for 24 hr and hospitalised for 14 days; *Age*: 5 younger children 1-3 yr; 8 older children 3-5 yr	Cross-sectional	Louisville Twin Study	Not considered	Yes (uninjured twin)	T1: Age 6 (1 -5 yr postoperatively)	Neuropsychological: WPPSI Psychosocial: parental ratings	Positive Age effects (neuropsychological): no difference between twins and controls who were injured between 12 and 36 mo; twins who were injured between 36 and 48 mo had lower scores than their cotwins on four of the performance sub tests; differences were small (< 1 SD) and still within the average range; due to the long injury-to-test intervals (1 - 5 years), we do not know whether the null effect for the younger injuries was due to sparing (i.e., no effect) or recovery Age effects (psychosocial): Twins injured between 12-36 mo had higher scores on an emotional factor; twins injured between 36-48 mo did not differ in ratings of emotionally or temperament
[24]‡ Max et al. (1998b)	*Mild* (n = 17): one of the following: LOC < 30 min, PTA ≤ 24h, any alteration in consciousness which does not result in LOC > 30 mins, initial GCS of 13-15 after 30 mins, PTA < 24 hours. *Moderate* (n = 12): exceeding mild but less than severe. *Severe* (n = 17): LOC > 24h, PTA > 7 days, Lowest post resuscitation GCS ≤ 8 *Age*: mean 6.14 yr	Cross sectional	Consecutive admissions to paediatric clinic	Preinjury psychiatric status taken into consideration	No	T1: mean years between injury and assessment 5.3 yr	Neuropsychological testing: Including WISC-III, WRAT Revised, Schedule for Affective Disorders and Schizophrenia for School-Age Children - epidemiologic version (K-SADS-E).	Adverse findings: Increased rates of ADHD and ODD/CD following MHI. While children developing ODD/CD had more family history of families alcohol dependence/abuse, there was no differences between children with no Hx of ADHD and those who developed ADHD following head injury. Weakness of study is reliance on retrospective assessment of preinjury psychiatric status & outcomes reported for HI group as a whole.

Study	Head injury definition	Design	Source of participants	Preinjury factors	Non head injured control group(s)	Follow-up(s)	Type of assessment	Reported outcome
[25]‡ Max et al. (1997a-c)	Mild (n = 26) lowest post resuscitation GCS score 13-15 irrespective of linear fracture Moderate (n = 9) GCS 9-12 or 13-15 with intercranial lesion or depressed fracture Severe (n = 15) lowest post resuscitation GCS score ≥ 8 *Age*: 6-14 yr	Prospective	Consecutive head injury admissions to 3 regional hospitals	Pre injury psychiatric status taken into consideration. Exclusion: Hx child abuse, previous head injury involving > 1 night hospital admission. CNS disorder and mental retardation	No	T1: 3 mo, 37 subjects returned for assessment, majority being moderate - severe T2: 6 mo T3: 2 yr, 42 subjects returned for assessment	K-SADS-E, supplemented by K-SADS-P sections on ADHD/ODD alcohol and substance abuse and PTSD module, NPRS. Vineland adaptive behaviour scale, measures of psychiatric history and family functioning and SES	Adverse: Novel psychiatric disorders were reported in 17/37 children during first 3 mo followup, 10/42 children at 6 mo, 16/44 at 1 yr and 15/42 at 2 yr. Psychiatric disorders were predicted by injury severity, pre injury family functioning and pre injury lifetime psychiatric Hx. This series of studies suggests that particular children may be vulnerable to the onset of new psychiatric disorders following MHI.
[26]‡ Overweg-Plandsoen et al. (1999)	*Mild* (*n* = 22): LOC less than 20 mins, PTA less than 15-20 min or two of following: headache, nausea and vomiting, decline of consciousness after lucid interval. *Age*: 0-12 yr	Cross-sectional	Accident & Emergency dept reports	No	Yes (orthopaedic control group)	T1: 2 yr	Questionnaire sent to parents containing yes/no questions related to existence of learning, behaviour concentration or physical problems since accident.	Adverse: Main symptoms headache, dizziness, fatigue & memory problems Total number of symptoms in CMH exceeded 4 times this in group of children with a fractured bone. Weakness of the study was that no preinjury characteristics were taken into account. Wide age range. Used multi-choice questionnaires with a high rate of non responders (55%).
[27] Papero et al. (1993)	*Mild* (*n* = 63): GCS 13 with or without evidence of skull fracture or bleeding with no CT evidence of parenchymal damage *Moderate* (*n* = 18k): GCS ≥ 13 with neuroimaging evidence of BD or GCS 9-12 *Severe* (*n* = 5):GCS=3-8	Cross-sectional	Registry of children with a head injury admitted to paediatric medical centre	Exclusion criteria: children with penetrating head wounds and evidence of child abuse	No	T1: 1-3 yr post injury	Neuropsychological: WISCR, Halstead-Reitan battery, VMI, Fuld Object Memory Evaluation (used only to correlate with VABS outcome) Psychosocial: VABS	Null Psychosocial: Results showed a non significantly higher rate of premorbid injuries of all kinds in the mild group and a non significantly higher rate of prior learning difficulties; the effects of injury severity on adaptive functioning was limited to younger boys in the moderate-severe group but not the mild group

Study	Head injury definition	Design	Source of participants	Preinjury factors	Non head injured control group(s)	Follow-up(s)	Type of assessment	Reported outcome
[28]‡ Pentland et al. (1998)	*Mild-Mod* (n = 17): not defined Severe (n = 16): not defined Age: 12-16 yr	Cross-sectional	Hospital admissions	Exclusions: Hx of neurological, psychiatric or learning disorders	Yes: non injured volunteers	T1: more than 18 mo post injury	WISC-III, A planning task	Null: No difference in planning skills or WISC-III scores were apparent for adolescents in the mild-mod group when compared with controls. Severe HI were significantly different to the controls. Used less efficient strategies in planning tasks and had significantly lower IQ scores. Results should be viewed with caution as not only were sample sizes for each group small, it is not possible to determine how different severity groups were defined.
[29]‡ Robin et al. (1999)	*Mild* (n = 28): lowest post-resuscitation GCS ≥ 13 *Moderate to severe* (n = 21): *Moderate*: lowest post-resuscitation GCS 9-12 *Severe*: lowest post-resuscitation GCS ≤ 8. *Age*: 6-16 yr	Cross sectional	University hospital admissions	Exclusions: Hx mental retardation, child abuse or HI	Yes (matched for age to orthopaedic injury control group)	T1: minimum of 2 yr post injury	Sustained attention assessed.	Adverse findings: MHI group had deficits in sustained attention demonstrating significant vigilance decrements. Subjects showed progressively declining performance on sustained attention task, not found on orthopaedic controls, referred to as attention fatigue by authors. Severe HI resulted in greater attentional deficits than either MHI or controls.
[30] Thompson et al. (1994)	*Mild-mod* (n = 35): GCS > 8 *Severe* (n = 14): GCS 58	Prospective	Neurosurgery unit in hospitals	Exclusion criteria: Hx of previous brain trauma, penetrating wound to the head, or injury to spinal cord; Hx of neurological handicap or severe behavioural disturbance, antecedent LD, or a failure to regain consciousness within 3 mo of the injury	No	T1: following resolution of post traumatic confusion T2: 6 mo post injury T3: 1 yr post injury T4: 2 yr post injury TS: 3 yr post injury T6: 4 yr post injury T7: 5 yr post injury	Neuropsychological: motor, visuospatial, and somatosensory skills	Indeterminate*

Study	Head injury definition	Design	Source of participants	Preinjury factors	Non head injured control group(s)	Follow-up(s)	Type of assessment	Reported outcome
[31]‡ Wrightson et al. (1995)	*Mild* (*n* = 78): attendance at accident department and having been diagnosed as having had a MHI not sufficient to warrant admission. *Age*: 2.5 - 4.5 yr	Longitudinal	Accident & Emergency dept	Exclusion criteria: Hx of HI	Yes (minor injury control group (*n* = 86), Found no difference between CHI and controls on a variety of preinjury factors)	T1: 1 mo T2: 6 mo T3: 12 mo T4: 2-4 yr at age 6.5 yr	Extensive battery of tests including: VABS, Conners Parent Questionnaire, Neale analysis of reading ability, sub tests of WISC-R, Tests of verbal and visual memory and visual perception.	Adverse: No differences on cognitive tests immediately after injury, but at 6 & 12 mo children scored < controls on visual puzzle. At 6.5 yr more likely to need help with reading. Authors concluded MHI was associated with subtle changes which could impact on school performance. This study used a large sample and an appropriate control group.
Maximum period of follow up after head injury of less than 1 year								
[32] Asarnow et al. (1995)	*Mild* (*n* = 137): uncomplicated injury, not requiring hospitalisation, from blunt forces. and characterised as concussion; AIS score 1, 2, or 3 *Age*: 8-16 yr	Prospective	Emergency rooms	Statistically controlled	Yes (n = 114)	T1: Within 1 mo post injury T2: 6 mo post injury T3: 12 mo post injury	Neuropsychological (extensive battery) Academic Psychosocial: CBCL and AIM	Null: Neuropsychological: After statistically and experimentally controlling for preinjury risk factors, no neuropsychological sequelae specific to MHI was found Psychosocial: No differences among groups on any of the domains of the AIM; results on the CBCL suggested that the parents of the mild group perceived a higher rate of problems in the 6-month period that preceded the accident than did the parents of the other groups, although none of these concerns were of clinical significance
[33]‡ Bassett et al. (1990)	Mild (*n* = 19): GCS 13 - 15 Severe (*n* = 10): GCS 4 -8 *Age*: adolescent, mean 15.7 yr	Cross-sectional	Treated at University trauma centre	No Hx of neurological deficits	Yes (n = 29) selected for similar age, education & SES	T1: within 2mo of injury	WAIS-R or WISC-R, WMS, Logical Memory & Visual Reproduction subtests, immediate & delayed recall, Buschke Selective Reminding Test, WCST, Trail Making Test, Controlled Oral Word Association Test.	Adverse: Mildly injured patients exhibited some dysfunction in verbally based measures of learning, abstraction, and reasoning. Unimpaired on measures of attention, motor speed & visual memory. Study weakened by small sample size.

Table 1. *(continued)* **Methodological Characteristics of Studies of MHI in Children and Adolescents (1970–2000)**

Study	Head injury definition	Design	Source of participants	Preinjury factors	Non head injured control group(s)	Follow-up(s)	Type of assessment	Reported outcome
[34] Bawden et al. (1985)	*Mild* (*n* = 47): LOC < 20 min (including linear skull fracture) *Moderate* (*n* = 23): LOC > 20 min, or neurological signs, EEG, or CT abnormality *Severe* (*n* = 17): GCS 3-7 and required ICP monitoring	Retrospective	Hospital patients who had received medical treatment for a head injury	Exclusion criteria: Previous neurological or behavioural disorders	No	T1: Approximately 1 yr after injury	Neuropsychological: modified Halstead-Reitan battery (including WISC-R)	Null: MS of the mild group were well within the average-to-above-average range on each standardised tests; however, no normal control group was matched to the mildly injured
[35]§ Casey et al. (1986)	*Mild* (*n* = 321): Hx with no signs of concussion, LOC, skull fractures, no hospital admittance, memory loss, or neurological impairment *Age*: 6 mo - 14 yr	Retrospective	Consecutive admissions to emergency room in hospital	Exclusion criteria: suspected child abuse	No (used questionnaire, with local norms for younger and older children)	T1: emergency room contact made and demographics gathered T2: parent questionnaire administered over the phone	Telephone questionnaire focused on physical, behavioural symptoms (sleep disturbance, moodiness, and discipline problems) and school attendance	Adverse: Results revealed substantial functional morbidity based on a behavioural screening questionnaire (younger group, 13. 1 % vs. 25.0%; older group, 2.7% vs. 27.1%); school absenteeism was also high for the preschool children (29% vs. 10% local preschool rates) and older children (40% vs. 19% local rates); no increase in reports of physical symptoms commonly associated with head injury; they attributed the increase in school absenteeism and behavioural problems to parental overreaction and possible family dysfunction
[36] Ewing-Cobbs et al. (1990)	*Mild* (*n* = 21): PTA ≤ 7 days *Moderate* (*n* = 7): PTA 8-14 days *Severe* (*n* = 9): PTA > 14 days	Prospective	Paediatric neurosurgery service in hospitals	Exclusion criteria: Previous head injury, acquired or congenital insults to the CNS, inadequate school achievement prior to the injury, and ESL	No	Acute: daily at bedside until PTA resolved T1: after resolution of PTA T2: 6 mo T3: 12 mo	Neuropsychological: Verbal and Nonverbal Selective Reminding Test	Adverse (mild): Performance on verbal memory test was interpreted as wit hin normal limits; performance on the nonverbal memory task was reduced at baseline but showed steady improvement and recovery by 12 mo; this interpretation is problematic, given the lack of a non injured control group to determine the status of the initial performance level as well as recovery versus practice effects; classification of children on the basis of a PTA < 7 days may have been comprised of children with more severe injuries

Study	Head injury definition	Design	Source of participants	Preinjury factors	Non head injured control group(s)	Follow-up(s)	Type of assessment	Reported outcome
[37] Ewing-Cobbs, Levin, et al. (1989)	*Mild-mod* ($n = 8$): concussion resulting in LOC < 24 hr and a GCS score ≥ 9, PTA ≤ 7 days *Age*: younger group: 4 months-3.5 yr; older: 3.5-7 yr	Cross-sectional	Paediatric neurosurgery service. in hospitals	Exclusion criteria: previous head injury, other acquired or congenital CNS insults. inadequate premorbid school achievement, and ESL	No	T1: following resolution of PTA T2: 6 mo post injury T3: 1 yr post injury	Neuropsychological: basic intellectual functions, language processing. and motor skills	Adverse: Mild- mod group was reduced on the baseline evaluation, as indicated by the significant increase in scores at 8 mo post injury; Ewing-Cobbs et al. concluded that this differential pattern of change indicated an initial performance deficit and subsequent recovery; this conclusion is problematic, given the lack of a non injured control group to determine the status of the initial level of performance as well as recovery versus practice effects Age effects: The express language disturbance in the mild-mod group was greater in the participant, suggesting that skills in a rapid phase of development may be more susceptible to the effects of brain injury
[38] Ewing-Cobbs et al. (1987)	*Mild* ($n = 23$): normal CT, LOC < 15 min. no neurological deficits *Moderate-severe* ($n = 33$): positive CT, LOC > 15 min	Cross-sectional	Neurosurgery service in hospital	Exclusion criteria: Hx of CNS insult, inadequate premorbid school achievement, evidence of neuropsychiatric disorder, indications of child abuse, lack of recovery to a testable level within 6 mo post injury	No	T1: approximately 1 mo post injury	Neuropsychological: focused on language tests (NCCEA)	Null: Mild group performed well within the average-to-above-average range on the composite language measures Age effect: Children were more impaired on written language than were adolescents; the researchers noted that written language functions may be more vulnerable to brain injury because incomplete stage of development in younger children
[39]§ Fletcher et al. (1990)	*Mild* ($n = 13$): admit GCS 13-15, LOC < 20 min, no skull fractures, mass lesion, swelling, or deterioration after admission *Moderate* ($n = 10$): admission GCS 9-12, or 13 - 15, with skull fractures and mass lesion *Severe* ($n = 22$): initial GCS 3-8 *Age*: 3-15 yr	Prospective	Paediatric neurosurgery service in hospitals	Exclusion criteria: Hx of head injury, acquired or congenital CNS insults, psychological disorder. LD, ADD. MR, or DD	No	T1: when resolution of PTA could be clearly documented T2: 6 mo post injury T3: 12 mo post injury	Neuropsychological: memory (CRMT, selective reminding) language (Word Fluency and PPVT), and perceptual -motor (VMI) Psychosocial: CBCL and VABS Severe: associated with declines in adaptive functioning Mild-mod: did not differ at average levels at follow-up points	Null Psychosocial: No impairment was found in adaptive functioning (VABS) or behavioural functioning (CBCL) at baseline or subsequent, follow-up assessments

Study	Head injury definition	Design	Source of participants	Preinjury factors	Non head injured control group(s)	Follow-up(s)	Type of assessment	Reported outcome
[40]‡ Greenspan et al. (1994)	*Minor* (*n* = 60): GCS 13-15 *Moderate* (*n* = 12): GCS 9-12 *Severe* (*n* = 19): GCS 3-8 *Age*: 5-15 yr	Cross Sectional	Hospital discharge information	Yes	Reference group	T1: 1 yr	Parental phone interview: Behaviour problems index, Rand scale on physical health	Adverse: 55% of the total HI group had difficulties in one or more areas of physical health (role activity, self care, mobility, physical activity). Head aches were the most commonly reported health problem. There was also increased behavioural problems and increased in enrolment in special education group. Children with severe injuries had more problems than mild group but all the HI children showed greater difficulties than a random selection of children the same age A weakness of the study was that information regarding family functioning and pre injury characteristics relied on recollection one year post injury.
[41]§ Gulbrandsen (1984)	*MHI* (*n* = 56 children-adolescents): Dx of concussion (LOC < 15 min or at least two post concussive Symptoms, such as amnesia, nausea, drowsiness, or somnolence) *Age*: 9-13 yr	Retrospective	Neurosurgical service in hospital	Exclusion criteria: more than one head trauma, Premature birth. developmental abnormalities, childhood disease that affected the brain, and psychiatric treatment	Yes (n = 56)	T1: 4-8 mo after being hospitalised for a concussion	Neuropsychological: standardised battery of 32 tests (including Reitan-Indiana and WISC)	Adverse: Test results showed significant differences between HI children and the control group on 29/32 tests, 7 of these were related to concussion; age effects, greater effect of CHI on neuropsychological performance in younger age groups (9 - 10) and (11 - 12), than on the older 13 yr group
[42] Hannay & Levin (1988)	*Mild* (*n* = 33): GCS 13-15, normal CT *Moderate* (*n* = 17): GCS 13-15 with abnormal CT; or GCS 9-12 *Severe* (*n* = 41): GCS ≤ 8	Cross-sectional	Neurosurgery service of hospital	Exclusion criteria: Hx of alcoholism, other neuropsychiatric disorder, or hospitalisation for CHI	Yes (n = 46)	T1: Mild M = 9 days, moderate M = 24 days, severe M = 79 days	Neuropsychological: CRMT	Null: no difference between percentage of outliers in the mild and control groups; no differences between the mild and control group in terms of hits, false alarms, and total correct; it should be noted that the mild group showed no impairment even though they were tested much earlier post injury than the other groups
[43] Jordan et al. (1990)	*Mild* (*n* = 10): GCS > 8 *Severe* (*n* = 10): GCS ≤ 8	Retrospective	Previous admissions to hospital	Exclusion criteria: Hx of head injury. intellectual handicap. acquired or congenital neurological disease or disorder	Yes (n = 20, other injury control group)	T1: at least 12 mo post injury	Neuropsychological: BNT	Null: No differences between mild-mod group and matched controls

Study	Head injury definition	Design	Source of participants	Preinjury factors	Non head injured control group(s)	Follow-up(s)	Type of assessment	Reported outcome
[44]‡ Kaufmann et al. (1993)	*Mild* (*n* = 11): GCS 13 - 15, impaired consciousness of ≤ 15 min, no CT evidence of intercranial lesion, no acute neurological deficit *Moderate* (*n* = 13): GCS 9 - 12 or 13 - 15 with presence of intercranial lesions on CT or acute neurological deficit *Severe* (*n* = 12): GCS ≤ 8 *Age*: 7 - 16 yr	Cross sectional	Consecutive hospital admissions	Exclusions: Preinjury HI resulting in an alteration of consciousness, acquired/congenital central nervous system insult, child abuse/neglect, psychological disturbance, LD, ADHD, mental retardation, other developmental disorders or persistent vegetative state	No	T1: 6 mo post injury	Continuous performance test & WISC-R digit span sub test	Null: While severe HI associated with impairment of attention, performance of mild to moderate groups approximated average score in normal children of similar age. Age effect: younger children with severe HI exhibited more pronounced impairment on continuous performance test relative to uninjured age peers.
[45] Knights et al. (1991)	*Mild* (*n* = 32): GCS 13-15, LOC < 20 min, admitted overnight, linear effects, no LOC *Moderate* (*n* = 18): GCS 8-12, LOC > 20 min abnormal CT, neurological deficit *Severe* (*n* = 20: GCS 7 or less, significant neurological deficits on CT	Prospective	Consecutive admissions to paediatric hospital	Exclusion criteria: Hx of neurological disorder, MR, or serious childhood disease	No	T1: hospital discharge T2: 3 mo after T1 T3: 9 mo after T1	Neuropsychological: WISC-R and modified Halstead-Reitan battery Academic: WRAT-R Psychosocial: Conner's Parental Questionnaire (asked to rate premorbid behaviour as well as current behaviour)	Null Neuropsychological: Tests most sensitive to head injury were those with a speeded motor or psychomotor component; in most of the tests, there was no difference between the mild and moderate groups, and performances were in the average-to-above-average range; a lack of a control group precludes a more direct test of the effects of MHI Academic: Mild group Ms were in the high average range on the WRAT-R . Psychosocial: 29% of parents in the mild group endorsed ≥ one change in behaviour from before the injury to the present time, which is consistent with post concussive symptom base rates in the general population
[46] Leahy et al. (1987)	*Mild* (*n* = 29): z score derived from GCS and length of hospital stay, z ≤ 0 = mild *Severe* (*n* = 13): z score of 1 SD > M *Ages*: 7-13 y	Cross-sectional	Consecutive admissions to paediatric neurosurgery service in hospital	Not considered	Yes (n = 46)	T1: 1 mo post hospital discharge T2: 6 mo post onset T3: 12 mo post onset	Neuropsychological: Token Test, EOWVT, PPVT, Word Fluency, CVLT, test recall, Rey-O Complex Figure, GP, trails, underlining test. VMI, and WISC-R Academic: WRAT-R	Null Neuropsychological: No differences between the mild group and the non injured control group on any of the neuropsychological measures; indeed. the M and percentile scores were almost identical in the mild and control groups, even on speeded psychomotor tasks Academic: WRAT-R M percentiles were almost identical for the mild and control groups

Study	Head injury definition	Design	Source of participants	Preinjury factors	Non head injured control group(s)	Follow-up(s)	Type of assessment	Reported outcome
[47] Levin et al. (1994)	*Mild-mod* (*n* = 49 + 24): GCS > 8 (M GCS for the younger group, 13.4; M GCS for the older group, 12.5) *Severe* (*n* = 24): GCS < 8 (M GCS for both older and younger group, 6.0)	Cross-sectional	Consecutive admissions to neurosurgery service in hospitals	Exclusion criteria: Hx of neuropsychiatric disorders, LDs, previous CHI, mental deficiency, and physical abuse	Yes (n = 89)	T1: minimum post injury interval of 3 mo	Neuropsychological: single cognitive task, TOL	Null: Although the Ms were identical for the mild-mod and control groups, the mild-mod group tended to break the rules more often than the controls (but less often than the severe group); MRI scans showed that the rule-breaking performance was more related to abnormal signal activity in the frontal regions than to injury severity; however, the question of MHI was confounded with moderate injury Age effect: Younger children showed more difficulty with problem solving and maintaining rules, although a ceiling effect may have existed for some of the older patients
[48]§ Levin et al. (1982)	*Mild-mod* (*n* = 30): GCS > 8 *Severe* (*n* = 30): GCS ≤ 8 (15 children and 15 adolescents in each group) *Age*: Mild-mod 5-12 yr Severe 2-12 yr	Cross-sectional	Chart review	Exclusion criteria: Hx of neuropsychological disorder through a review of the school records and detailed developmental Hx	No	T1: after resolution of PTA T2: (only for patients who exhibited problems at baseline) severe: 1-52 mo; mild: 2.0-2.3 mo	Neuropsychological: WISC-R selective reminding test, and CRMT	Null: Results showed a robust dose effect at baseline with more impairment in the severe group than in the mild-mod group; M scores of the mild-mod group were in the average range Age effect: Younger group showed poorer recovery at 12 mo; however, findings could have been confounded by ceiling effects for the older children
[49] Levin & Eisenberg (1979a)	*Grade 1* (*n* = 38): conscious on admittance, only momentary LOC, no neurological deficits; 1/3 of those referred for CT had abnormal findings *Grade 2* (*n* = 7): LOC < 24 hr or neurological deficits *Grade 3* (*n* = 19): LOC > 24 hr *Younger*: (*n* = 22) 6-12 yr old, (*n* = 44) 13-16 yr old	Cross-sectional	Neurosurgical service in hospital	Exclusion criteria: Hx of neuropsychiatric disorder, LD, or inability to cooperate with neuropsychological assessment, plus school records and developmental Hx were reviewed prior to inclusion into the study	No	T1: Most were tested during initial hospitalisation, but some were tested later T2: approximately 1 mo post injury (Mdn = 19 days, range 1-185 days)	Neuropsychological: WISC-R or WAIS-R, aphasia screening. visuospatial and visuomotor abilities, memory (Bushke), and somatosensory perception and motor speed	Adverse: Mild: A small of outliers (which ringed from 12-25%) primarily on tests of language. visuospatial ability, and memory; unfortunately the authors provided no chi square test on these proportions to determine whether there was an effect of mild head injury; use of reference norms provides no information on the expected number of outliers by age category for each test (as well as practice effects); without a normal control group and a follow-up assessment, it is difficult to determine whether an initial effect existed and whether it remitted over time Age effect: No age at injury effect between children and adolescents appeared. although only a few memory tests were given to the children

Study	Head injury definition	Design	Source of participants	Preinjury factors	Non head injured control group(s)	Follow-up(s)	Type of assessment	Reported outcome
[50] Light et al. (1987)	Not defined	Cross-sectional	Outpatient treatment centre	Exclusion criteria: preexisting brain dysfunction (normal cognitive and adaptive functioning prior to injury)	Yes (n = 60 other injury; n = 21 non injured controls)	T1: at least 1 yr after emergence from PTA	Neuropsychological: KABC, category test, EOWVT, Verbal Fluency, Continuous Performances Test. Span of Apprehension, and memory battery	Indeterminate*
[51] Mattson et al. (1990)	*Mild* (*n* = 15): GCS ≥ 13 without focal MRI lesions or evidence of upper extremity injury	Prospective	Hospital admissions	Exclusion criteria: Hx of LD or neuropsychiatric, disorder	Yes (n = 32)	T1: baseline T2: 6 mo post injury T3: 1 yr post injury	Neuropsychological. speeded motor tasks (Trails A and B, GP), verbal memory task (VSR)., nonverbal memory task (CRMT)	Adverse: Some differences between the control and CHI groups at baseline for GP non dominant hand, VSR (p < .05), and CRMT (p < .01) Age effects: Older mild CHIs had more difficulty on both of the memory tests and the younger mild CHIs had more difficulty on the GP; difference between the mild CHI and the controls, and the older and younger CHIs disappeared at 6 mo and 12 mo (except for CRMT in the older mild CHIs Ages 10-15); however. the M score for the control group was nearly 2 SD > M of the normative sample, and it may not have been an appropriate comparison group
[52]‡ Mittenberg et al. (1997)	*Mild* (*n* = 38): GCS 13-15 , normal CT, no skull fractures *Moderate to severe* (*n* = 27): GCS < 13 or with abnormal CT or skull fracture *Age*: 6 - 15 yr	Cross sectional	Consecutive hospital admissions	Developmental Hx assessed	Yes (orthopaedic injury group)	T1: 6 wk post injury	Structured symptom check list consistent with paediatric post concussion syndrome as defined by ICD-10 and DSM-IV	Adverse: Different from controls on a variety of post concussive symptoms including attentional, headaches, memory difficulties, dizziness and anxiety. 11% of the moderate-severe and 16% of the mild head injury group were asymptomatic compared with 40% of controls. Symptoms were related to HI severity and anxiety level. A weakness of the study was that it relied on the HI child as sole informant.
[53]‡ Ponsford et al. (1999)	*Mild* (*n* = 130): LOC less than 30 min, PTA of less than 24 hours. GCS of 13-15 on presentation at emergency room. *Age*: 6-15 yr	Prospective	Accident & Emergency dept	Found no difference between CHI and controls on a variety of preinjury factors Statistically controlled for a number of preinjury factors	Yes (minor injuries not involving the head with a possible stay of < 24 hr)	T1:1 wk T2: 3 mo	Behavioural assessment: CBCL and Rowe Behavioural Inventory, Post Concussion Syndrome Checklist. Neuropsychological battery: Including sub tests of the WISC-III, PPVT and WRAML.	Null: MHI children showed no cognitive impairment relative to controls at either 1 wk or 3 m post injury. Increased reports of headaches and dizziness evident at 1 week post injury had resolved by 3 months post injury. 17% of children continued to show deficits at 3 mo, Hx of previous injury & premorbid stressors were found to be significantly related to continuing deficits.

Study	Head injury definition	Design	Source of participants	Preinjury factors	Non head injured control group(s)	Follow-up(s)	Type of assessment	Reported outcome
[54]‡ Prior et al. (1994)	*Mild* (*n* = 37): coma > 5 min but < 1 hr *Mod* (*n* = 10): coma 1 hr - 24 hr *Severe* (*n* = 13): coma >24 hr *Age*: 6 - 16 yr	Longitudinal	Consecutive admissions to a children's hospital	No Hx of HI or neurological disorders	No control group, tests with normative data used	T1: as soon as possible, 3-16 wk post injury T2: 6 mo post injury	Neuropsycological tests: Buschke Selective Reminding Test, WISC-R, Austin Maze, WAT-R, Rey Figure & WCS Psychosocial tests: CBCL, TRF, General Health Questionnaire & McMaster Model Family Assessment Device	Null: no deficits detected for children in the MHI group on any of the neuropsychological tests at either follow up time. Children with mod-severe HI showed deficits on measures of reading and spelling and had lower WISC-R scores at both time periods. Family and parental functioning was in the normal range. No consistent indication of behavioural problems in the HI groups.
[55] Slater & Kohr (1989)	*Mild* (*n* = 20): GCS 13-15 *Moderate* (*n* = 3): GCS 9-12 *Severe* (*n* = 11): GCS 3-8	Cross-sectional	Trauma units or paediatric ICU of hospital	Found no difference between CHI and controls on a variety of preinjury factors	Yes (n = 32)	T1: during initial hospitalisation T2: 6 mo post injury (CHI group only)	Neuropsychological: WISC-R or WAIS-R, PPVT, and GORT Academic: WRAT-R	Indeterminate*
[56]§ Tompkins et al. (1990)	Several measures of severity were treated as continuous variables. (*n* = 38) GCS = 15; (*n* = 33) GCS = 9-14; (*n* = 13) GCS ≤ 8. *Age*: 5-16 yr	Prospective	Consecutive hospital admissions	Exclusion criteria: Hx of psychiatric illness; used regression analysis to look at physical, psychological, or cognitive disorders and occupation and marital status of parents	Yes (n = 88)	T1: 1 mo T2: 6 mo T3: 12 mo	Neuropsychological: CVLT, digit span. Ray-O Complex Figure, VMI, trails, GP, underlining tests, PPVT, grammatical comprehension, TOAL, Token Test, EOWVT, Word Fluency. Cookie Theft, Rapid Automatised Naming Test, and story retelling	Indeterminate*
[57] Winogron et al. (1984)	*Mild* (*n* = 17): LOC < 20 min (including linear skull fractures) *Moderate* (*n* = 17): LOC > 20 min, or neurological signs, EEG, or CT abnormality *Severe* (*n* = 17): GCS 3-7 and required ICP monitoring (mild M age: 10.7; moderate M age: 10.4; severe M age: 10.4)	Retrospective	Hospital patients who had received treatment for a head injury	Exclusion criteria: previous head injury, psychiatric treatment, hyperactivity, speech problems with EEG abnormality, or overactivity in combination with behavioural or learning difficulties	No	T1: 0.9- 1. 1 yr post injury	Neuropsychological: WISC-R, PPVT, Category Test, Tactual Performance Test, Tapping Test, Finger Agnosia, GP, Aphasia Screening Battery, Sentence Memory Test, Fluency Test, Target Test, and trails Academic: WRAT	Null: Ms on tests in the mild group were well within the average-to-above-average range and differed significantly from the severe group; however, on two of the tests, approximately 15% of the mild group were impaired; unfortunately, the lack of a control group makes it difficult to determine whether the proportion of participants on these two tests was significantly different from a matched non injury control group

Study	Head injury definition	Design	Source of participants	Preinjury factors	Non head injured control group(s)	Follow-up(s)	Type of assessment	Reported outcome
[58]‡ Yeates et al. (1999)	*Mild* (*n* = 26): LOC < 30 mins, GCS ≥ 13, loss of memory for events surrounding accident, or alteration in mental state at time of accident. *Age*: 8-15 yr	Prospective longitudinal	Accident & Emergency dept	Exclusions include: required surgical intervention or had multiple trauma, Hx of previous HI, neurological disorder, mental retardation or injury a result of abuse and control for preinjury characteristics	Yes (use of siblings)	T1: 7 days after injury T2: 3 mo after injury	Behavioural assessment: CBCL Neuropsychological testing including WISC-III short form, WISC-III digit span & coding sub tests, WCS, CVLT, Trailmaking test & Childrens Paced Serial Addition test	Adverse: 35% of the children showed increases in post concussive symptoms and were more likely to show distractibility, tiredness & difficulty maintaining attention. Those with increased PCS symptoms showed poorer neuropsychological functioning, demonstrated poorer behavioural adjustment, decreased motivation when compared with HI children without PCS. These differences were partially resolved at 3 mo post injury. Small sample size is a weakness along with small control group (only 8 siblings controls were used for the HI group).
[59] Yeates et al. (1995)	*Mild-mod* (*n* = 13): GCS > 8, impaired consciousness < 1 day *Severe* (*n* = 34): GCS = 8 or less, impaired consciousness > 1 day *M* age at injury: 10 yr, 4 mo (SD = 37 mo); M age at testing: 11 yr, 1 mo (SD = 34 mo)	Cross-sectional	Neuropsychology service	Exclusion criteria: Hx of head injury or other neurological disorder, special education or grade retention, DD, or ADHD	Yes (n = 47)	T1: 9 mo (M interval between injury and testing; SD = 11 mo; 70% tested within 1 yr of injury)	Neuropsychological: focused on memory (CVLT) as part of a larger neuropsychological battery	Indeterminate*
No defined period of followup / non specific outcomes								
[60]‡ Leathem & Body (1997)	*Mild-mod* (*n* = 18): mild 5 - 60 min PTA, mod 1 - 24 hr PTA *Age*: 11-14 yr at time of injury	Retrospective	Year 10 school students from a local secondary school (predominantly 14 yr olds)	Not considered	Yes: control group from year 10 students (n = 17)	T1: No uniform followup time, up to 3 yr post injury	Self-report questionnaire: regarding general functioning and symptoms. Neuropsycholgical tests: AVLT, PASAT, Digit symbol subtest from WISC-R, Word Fluency test, Teacher Report Form and Behaviour Checklist (TRF) (adapted from CBCL). An adapted form of the TRF was used with parents	Null: Neropsychological Test: no significant difference between MHI group and controls on any neuropsychological tests, apart from two trials of the AVLT which the head injured group scored lower. Self-report questionnaire: significant difference between HI group and control group on symptom measure but not on measures of general functioning. While there was some indication of deficits in the HI group this finding is weakened small sample size and the reliance on the accuracy of self-report data.

Study	Head injury definition	Design	Source of participants	Preinjury factors	Non head injured control group(s)	Follow-up(s)	Type of assessment	Reported outcome
[61]‡ Max & Dunisch (1997)	*Mild* (*n* = 64) not mod-severe, definite HI consisting of one or more of following: Hx LOC, 24hr admission for observation, evidence of decreased adaptive functioning, skull fracture, seizure or concussion *Mod-Severe* (*n* = 10) abnormal CT scan, depressed skull fracture, LOC > 30 min or requirement of neurosurgery *Age*: mean 5.26 yr	Archival	Chart review of children presenting to an outpatient facility over a 3 yr period	Excluded injuries to head without PCS, Hx of neurological disorders	Yes: Children from same outpatient clinic with no Hx of HI, matched by age, sex, race, social class	No uniform follow time	Axis I & II assessments, use of special education services, IQ scores	Null: 3/59 of the comparisons made between HI and control groups were significant. HI group were significantly different from the controls on developmental communication disorder cluster. Autism and pervasive developmental disorder cluster were more frequent in the control group. It was concluded that children presenting to psychiatric clinics with Hx of HI were indistinguishable from matched controls.
[62]‡ Michaud et al. (1993)	Not defined, has to have suffured a head injury (with medical records available indicating positive LOC or concussion) prior to being enrolled in special education services for bahavioural disorder *Age*: 14/16 less than 5 yr at time of injury	Retrospective	From grades 1-5 of a local elementary school	Exclusion from the study if there was behavioural disability associated with another handicapping categoiries such as learning, hearing, visual or mental disabilities	Yes: children from the same school who were not receiving any special services; matched for age, grade, race, gender, socioeconomic status	No uniform followup time	Parental questionnaire	Adverse: children who suffered a HI prior to age 5 were 8.7 times more likely to be subsequently enrolled in special educatrion service for behavioral disorders and 3.3 time more likely if the injury occurred after 5 yr of age.
[63]‡ Segalowitz & Lawson (1995)	Not defined Age: 0-time of assessment, mean age at injury 8.5 yr	Retrospective	From 3 Urban high school survey and an introductory university class	Not considered	Yes (compared those having a reported CHI with those who did not report a head injury)	No uniform follow time	Self-report questionnaire	Adverse: Wide range of psychological and educational symptoms reported including sleep difficulties, social difficulties, increased left handedness, increased diagnosis of attention deficit, depression and speech and language and reading disorders. These findings be viewed cautiously as they relied on a self report questionnaire and there was a lack of a clear definition for MHI

Study	Head injury definition	Design	Source of participants	Preinjury factors	Non head injured control group(s)	Follow-up(s)	Type of assessment	Reported outcome
[64]§ Segalowitz & Brown (1991)	Not defined *Age*: 1-17 yr	Retrospective	Urban high school survey	Not considered	Yes (compared those having a reported CHI with those who did not report a head injury)	No uniform follow time	Self-report questionnaire	Adverse: participants who reported an MHI also reported an increased rate of speech difficulty (stuttering), left handedness, attention deficit-hyperactivity, and math difficulty; given the lack of any control for preinjury factors, the use of a self report questionnaire, as well as ambiguities regarding case definition, these results should be viewed with caution

Note: **ADD** = attention deficit disorder, **ADHD** = attention deficit- hyperactivity disorder; **AIM** = Attention, Impulsivity, and Memory Questionnaire; **AIS** = Abbreviated Injury Scale; **AVLT** = Auditory Verbal Learning Test; **BD** = brain damage; **BNT** = Boston Naming Test; **CBCL** = Child Behavioural Checklist; **CHI** = closed head injury; **CIQ** = Community Integration Questionnaire; **CNS** = central nervous system; **CT** = computerised tomography; **CRMT** = Continuous Recognition Memory Test; **CVLT** = California Verbal Learning Test; **DD** = developmental disability; **DSM-IV** = Diagnostic & Statistical Manual of Mental Disorders (4th ed.); **Dx** = diagnosis; **EEG** = electroencephalogram; **EOWVT** = Expressive One-Word Vocabulary Test; **ESL** = English as a second language; **FIQ** = full-scale IQ; **GCS** = Glasgow Coma Scale; **GDS** = Gordon Diagnostic System; **GORT** = Grey Oral Reading Test; **GP** = Grooved Pegboard (test); **Hx** = history; **ICD-9/10** = International Classification of Diseases (9/10th ed.); **ICP** = intracranial pressure monitoring; **ICU** = intensive care unit; **KABC** = Kaufman Adaptive Behaviour Scale; **K-SADS-E** = Schedule for Affective Disorders and Schizophrenia for School-Age Children - epidemiologic version; **K-SADS-P** = Schedule for Affective Disorders and Schizophrenia for School-Age Children - child present episode version; **LD** = learning disability; **LOC** = loss of consciousness; **MHI** = mild head injury; **mild-mod** = mild and moderate cases; **mo** month(s); **MOS-SF36** = Medical Outcome Study - Short Form 36; **MR** = mental retardation; **MRI** = magnetic resonance imaging; **NCCEA** = Neurosensory Centre Comprehensive Examination for Aphasia; **NPRS** = Neuropsychiatric Rating Schedule; **PIQ** = performance IQ; **PPVT** = Peabody Picture Vocabulary Test; **PASAT** = The Paced Serial Addition Task; **PTA** = post traumatic amnesia; **SES** = Socioeconomic Status; **T#** = time; **TOAL** = Test of Adolescent Language; **TOL** = Tower of London; **TRF** = Teacher report Form; **VABS** = Vineland Adaptive Behavioural Scales; **VMI** = Beery Visual Motor Integration Test; **VSR** = visual selective reminding; **WAIS-R** = Wechsler Adult Intelligence Scale-Revised; **WCS** = Wisconsin Card Sort; **WISC-R** = Wechsler Intelligence Scale for Children- Revised; **WISC-III** = Wechsler Intelligence Scale for Children- version III; **wk** = week(s); **WPPSI** = Wechsler Preschool and Primary Scale of Intelligence; **WRAML** = Wide Range Assesment of Memory And Learning; **WRAT-R** = Wide Range Achievement Test-Revised; **yr** = year(s).

* Studies with indeterminate outcomes did not contain, nor were they typically designed to have, a specific contrast between MHI and a matched non injured group, a contrast between a mild and more severely injured group (moderate or severe) or both on, standardised tests. Many of the studies in the indeterminate category addressed objectives such as dose effects, age-at-injury effects, quality of life issues or injury and demographic factors related to neuropsychological outcome.

(Adapted from Satz et al. 1997)

§ Studies included in the Satz et al. 1997 review but modified or added to in this table: (n = 13).

‡ Additional studies reviewed in this table: (n = 23).

Table 2 Studies of Mild Head Injury in children Classified by Outcome
(corresponding reference in Table 1)

Cognitive outcomes	Finding
[10] Barnes et al. (1999)	adverse
[33] Bassett et al. (1990)	adverse
[17] Dennis et al. (1995)	adverse
[36] Ewing-Cobbs et al. (1990)	adverse
[37] Ewing-Cobbs, Levin et al. (1989)	adverse
[41] Gulbrandsen (1984)	adverse
[20] Klonoff et al (1977)	adverse
[1] Klonoff et al. (1993)	adverse
[49] Levin & Eisenberg (1979a)	adverse
[21] Levin & Eisenberg (1979b)	adverse
[22] Lundar & Nestvold (1985)	adverse
[23] Lyons & Matheny (1984)	adverse
[51] Mattson et al. (1990)	adverse
[29] Robin et al. (1999)	adverse
[64] Segalowitz & Brown (1991)	adverse
[63] Segalowitz & Lawson (1995)	adverse
[31] Wrightson et al. (1995)	adverse
[32] Asarnow et al (1995)	null
[34] Bawden et al. (1985)	null
[11] Bijur et al. (1990)	null
[14] Butterbaugh et al. (1993)	null
[15] Chadwick et al. (1981)	null
[16] Chapman et al. (1992)	null
[3] Costeff et al. (1988)	null
[18] Ewing-Cobbs et al. (1998)	null
[38] Ewing-Cobbs et al. (1987)	null
[4] Godfrey (2000)	null
[42] Hannay & Levin (1989)	null
[43] Jordan et al. (1990)	null
[6] Jordan et al. (1992)	null
[44] Kaufmann et al. (1993)	null
[45] Knights et al. (1991)	null
[46] Leahy et al., (1987)	null
[60] Leathem & Body (1997)	null
[47] Levin et al (1994)	null
[48] Levin et al. (1982)	null
[27] Papero et al. (1993)	null
[28] Pentland et al. (1998)	null
[53] Ponsford et al. (1999)	null
[54] Prior et al. (1994)	null
[57] Winogron et al., (1984)	null
Psychiatric Outcomes	**Finding**
[24] Max et al. (1998b)	adverse
[25] Max et al. (1997a-c)	adverse
[13] Brown et al. (1981)	null
Behavioural Outcomes	**Finding**
[8] Andrews et al. (1998)	adverse
[9] Asarnow et al. (1991)	adverse
[11] Bijur et al. (1990)	adverse
[35] Casey et al. (1986)	adverse
[40] Greenspan et al. (1994)	adverse
[62] Michaud et al. (1993)	adverse
[52] Mittenberg et al (1997)	adverse
[26] Overweg-Plandsoen et al. (1999)	adverse
[58] Yeates et al. (1999)	adverse
[32] Asarnow et al. (1995)	null
[39] Fletcher et al. (1990)	null
[4] Godfrey (2000)	null
[45] Knights et al. (1991)	null
[19] Kinsella et al (1999)	null
[53] Ponsford et al. (1999)	null

*Studies with indeterminate findings (7) or non specific outcomes (3) have not been included in the table

1984: *57*). Details on each of these studies and the different methodologies used are summarised in Table 1. While each of these studies have used similar neuropsychological testing batteries, the extent to which comparisons can be made between them is doubtful. Not only do the ages of the children at the time of injury differ between studies, but time of assessment post-injury also varies widely. Only five of the studies have tested head injured children five years or more post-injury, two of these studies reporting deficits and three reporting no deficits. The key studies that have used general intelligence tests or comprehensive neuropsychological testing to assess outcomes following mild head injury have been selected for a detailed review below.

One of the most influential studies in the area of cognitive outcomes for children with mild head injury was conducted by Chadwick et al. (1981: *15*). This 27 month long prospective study of children following head injury investigated the pattern of intellectual and scholastic impairment and recovery. Thirty-one of the children were classified as having suffered a severe injury with a Post Traumatic Amnesia (PTA) of greater than 7 days, and 29 of the children were classified as mild with a PTA exceeding one hour but less than seven days. A third group with hospital-treated orthopaedic injuries were matched to the children with severe head injury. Individual psychological testing, including a shortened version of the Wechsler Intelligence Scale for Children (WISC), was conducted with each child after recovery from PTA and at 4 months, 1 year and 27 months after injury. Both the severe and mild head injury groups had Performance and Verbal IQ scores that were lower than the control group, but as the mild group demonstrated no recovery curve, their deficits were believed to have predated the injury. On the other hand, children in the severe injury group demonstrated marked deficits at all stages of follow up with evidence of progressive improvement. This was taken by the authors to indicate a strong association between injury and cognitive deficits.

A number of conclusions were drawn by Chadwick and colleagues (1981) in regard to children with mild head injuries. Although the children in the mild head injury group showed improvement over time, it was proposed that this did not exceed the changes seen in the control group and could, therefore, be attributed to practice effects rather than any sign of recovery. One problem with this conclusion, however, was that the children in the mild head injury group were given fewer tests by comparison to the severe group and their controls. Also, conclusions were made by comparing only one group of control children with the mild head injured children, even though this control group was individually matched with the children in the severe head injury group, not those in the mild head injury group.

To overcome the lack of matched controls for the mild injury group, Chadwick et al. (1981) chose to divide this group into two subgroups, those with PTA of less than 24 hours and those with a PTA of greater than 24 hours. This analysis indicated that Performance IQ in the more severely injured mild subgroup was significantly lower, suggesting that cognitive deficits were, in fact, present in some of the mild head injury group. Yet, the authors classified this deficit as transient because it no longer met their criterion of one standard deviation below the mean at the one year follow up. However, a difference of one standard deviation represents an extremely large effect size (Cohen, 1988) which is probably a far too stringent criterion for the potentially important effects of mild head injury. For example, an effect size of one standard deviation equates to a binomial effect size (BES, $r = 0.45$) of 45%; that is, an increase in the occurrence of problems in the index group from 27.5% to 72.5% (Rosenthal & Rubin, 1982). The relatively short follow-up time in the Chadwick study also meant that there was no information to evaluate whether the apparent deficits in the mild head injury group equated to normal cognitive performance in the long term.

The Asarnow et al. (1995; *31*) study was one of only three studies identified by Satz et al. (1997) in their review of literature in the area which met all six criteria they identified as crucial for the study of outcomes following mild head injury. Children aged between 8 and 16 were included in the study if they had experienced a mild injury rated at levels 1 to 3 on the Abbreviated Injury Scale (AIS). Two comparison groups were used, another injury group consisting of children admitted to the same hospital but not having injury to the head and a non injury group. There were three major domains of interest: measures of neuropsychological functioning 1 month post-injury, behaviour problems both for the six months prior to, and, the 12 months following injury and problems with school functioning 12 months post-injury. A range of neuropsychological tests were used to assess aspects of memory (as measured by Prospective Memory Test; Word List Memory Test/Release from the Proactive Interference; and Picture Memory Test), attention (as measured by Span of Apprehension, a test of selective memory; and Degraded Stimulus Continuous Performance Test, a test of sustained attention) and executive functioning (as measured by the Peabody Picture Vocabulary Test (Revised); Color Trails Test; Stroop Test; and Symbol Digit Substitution Test). The results at one month indicated a significant group effect for aspects of memory and an almost significant group effect for attention, but, these effects were no longer significant at either the 6 or 12 month follow up. However, the observed deficits were reported by Asarnow et al. (1995) to be the result of differences between both injury groups and the non injury group and so could be attributed to the non specific effects of incurring an injury. Asarnow et al. (1995) concluded that the head-injury group showed no clinically significant neuropsychological impairment when compared to the other injury group at either 1 or 12 months post-injury.

While both Asarnow et al. (1995) and Chadwick et al. (1981) reported findings which suggested a lack of cognitive deficits following mild head injury in children, both have relied on relatively short periods of follow-up. Other research suggests that a number of children with mild head injury will experience difficulties in later life despite apparent normal functioning as indicated by performance on some measures sooner after injury (Klonoff, Clark & Klonoff, 1993). As Koskiniemi, Kyykka, Nybo and Jarho (1995) stated, "Normal school performance or normal intelligence functioning is not a guarantee for good long-term prognosis."
Unlike Chadwick et al. (1981), Asarnow et al. (1995) used a non injured control group that was matched to the mild head injury group for gender and age and was demographically similar. However, this latter study suffered from other methodological problems. It relied on two assumptions; the accuracy of retrospectively collected information and the appropriateness of an 'other injury' group as a control. Both these issues are discussed in some depth in section 1.4.5. Research indicates that parents are inaccurate when asked to recall aspects of their children's development. Further, there is some doubt as to whether another injury control is appropriate for the study of outcomes following mild head injury.

Bijur et al. (1990: *11*) is the second of the three studies identified by Satz et al. (1997) as meeting all six criteria for the study of outcomes following mild head injury in children. This study was unique for its prospective longitudinal design, assessing the sequelae of mild head injury 1 to 5 years after injury. Data from a longitudinal study of 13 000 children in Britain was used to assess outcomes following mild head injury that occurred between the ages of 5-10 years. In addition to the mild head injury group, four other groups of children were selected for analysis: those with limb fractures, burns, lacerations and a group of children who had not suffered an injury between 5 and 10 years of age. Children were assigned to an injury group using the following descending hierarchy: head injury, burn, fracture and laceration. One positive feature here, seldom controlled in other studies, is that children were excluded from all five groups if they had suffered a head injury between the ages of 1 and 5 years. Bijur et al. (1990) reported null findings on measures of cognition (as measured by four sub tests of the British Ability Scale; and the Child Health and Education Study Language Pictorial Comprehension Test) and academic achievement (as measured by the Friendly Maths Test, a test specifically devised for the study; and a shortened version of the Edinburgh Reading Test).

While Bijur et al. (1990) concluded that there was little evidence for cognitive deficits following mild head injury, Rutter (1996) stated that their opinion was based on measures which were "... relatively crude and certainly not designed to pick up the kind of subtle cognitive impairments that have been associated with mild head injuries in the investigations reporting positive findings"pp.184 . Another weakness of the Bijur et al. (1990) study was that it required parents to accurately identify details of their child's injury events up to five years retrospectively. Other research indicates that parents show considerable inaccuracies when they are asked to retrospectively report aspects of their child's development (Chess, Thomas & Birch, 1966; Oates & Forrest, 1984; Robbins, 1963; Vobecky, Vobecky & Froda, 1988). After parental and study exclusions, only 114 children were identified by Bijur et al. (1990) as having suffered a mild head injury of sufficient severity to be classified as concussion. This prevalence rate differs from a New Zealand prospective cohort (Langley, Cecchi & Silva; 1987; Langley & Silva, 1985; Langley, Silva & Williams, 1981) which found approximately 5% of children suffered a mild head injury over the same age range. Thus, around 650 children, nearly 6 times the number reported, could have been expected to have suffered a head injury in the total sample of 13 000 children in the Bijur et al. (1990) study, indicating that, at least with regard to head injuries, those parents did show problems in their retrospective recall. The lack of reported findings may also be due to the relatively mild nature of the head injuries experienced by the children. Most (49/114) of the children in this study had not required hospitalisation and had only one or two symptoms of concussion. Nonetheless, one positive finding reported by Bijur et al. (1990) was that children in the head injury group were rated by their teachers as showing higher levels of hyperactivity at four tenths of a standard deviation above the mean rating of the uninjured children (i.e., Cohen's d = 0.4, a medium effect size).

In contrast to the substantially negative findings of the previous study, Gulbrandsen (1984: *41*), the third study identified by Satz et al. (1997) as meeting all six criteria for a methodologically strong study, found deficits associated with mild head injury. Gulbrandsen (1984) examined outcomes for 56 children aged between 9-13 years, 4-8 months following mild head injury. Mild head injury was defined as the presence of two symptoms of concussion, or unconsciousness which did not exceed 15 minutes. Gulbrandsen (1984: *41*) is one of the few studies in the area of mild head injury to set a lower criteria, thus ensuring that all children included in the head injury group had in fact experienced a head injury. A control group was selected by the teachers to be as similar as possible in terms of age, sex and of the same academic level as the head injured children prior to their injury. Outcomes were tested using the Reitan-Indiana Test Battery for Children and the WISC. In addition, parents were interviewed regarding their child's post-injury behaviour. Significant differences were found between the children in the mild head injury group and the control group on 29 out of the 32 test variables. However, only 7 of these variables were related to mild head injury.

As Gulbrandsen (1984: *41*) points out, despite the fact that the children in this study experienced relatively mild injuries, there were still a number of deficits evident. A major weakness of this study was the reliance on retrospective reports from the parent and teacher regarding pre-injury functioning of the child. In addition, there was no control for potential confounding variables associated with family functioning. While Satz et al. (1997) identifies longitudinal follow up as a strength of this study, the children were only examined at one point in time with a maximum follow- up interval of 8 months post-injury. As such, this study cannot be considered as meeting all six of the criteria that were recommended by Satz et al. (1997). Further, the relatively short period of follow up meant that potential long term problems could not be identified.

In contrast, Klonoff et al. (1977: *20*) presented results from a five year prospective study where the subjects' age at injury ranged from 2.7 to 15.9 years. Selection was based on consecutive admissions of children to two university hospitals during 1967-1968 with a diagnosis of head injury. Injury severity ranged from minor (suspected, but not proven loss of consciousness, no evidence of concussion), to serious (loss of consciousness for more than 30 minutes, concussion, skull fracture or other sequelae e.g., psychosis, aphasia etc.). One hundred and thirty one of the head injured children were less than 9 years old at time of injury and 100 were older than 9 years of age. Each child was matched by age and gender with a normal control giving three groups of children, younger, older and controls. The children were evaluated during initial admission using a number of neuropsychological tests including the WISC and the Reitan-Indiana Neuropsychological Test Battery for Children. At the initial admission testing period, significant differences in IQ scores were apparent for the head injured groups by comparison to their controls. Also at this time, differences were evident between groups on 28 of the possible 32 neuropsychological variables for the younger group and on 42 out of 48 for the older group. In this study impairment had to be present on both the fourth and fifth follow-up for classification of residual impairment to be given. While a substantial number of the children made a marked recovery over the initial five year follow-up period, more than 23% of the children still showed evidence of residual impairment on neuropsychological testing.

One hundred and fifty-seven of the original subjects from the previous study were still available for evaluation when adult, twenty three years after injury (Klonoff et al., 1993: *1*). At this time, subjective sequelae, categorised as physical, intellectual and emotional, were reported by 31% of the sample. The most common cognitive sequelae reported by this group as being related to the head injury were difficulties in learning, memory, concentration and speed of thought processes. Sequelae were reported to be related to the extent of the head injury and initial IQ. The continuing difficulties into adulthood suggest that long term follow-up is necessary to fully appreciate outcomes following childhood head injury.

However, there were a number of difficulties associated with the Klonoff et al. (1993) study. Evidence of continuing deficits in adulthood for individuals who had experienced head injury during childhood relied on the reporting of subjective symptoms as no objective measures were used. Also, approximately 81% of the adults in the study were reported to have had evidence of either a linear or depressed skull fracture. It is likely therefore, that the children used in the longitudinal study by Klonoff et al. (1977, 1993) represented a more seriously injured sample than those used by Bijur et. (1990) which may explain the vastly different outcomes of these two studies. Another major difficulty associated with the Klonoff et al. (1993) study is that information was only reported for the head injured group as a whole, making it impossible to distinguish outcomes for different levels of severity.

1.3.2 Attentional Outcomes

Attention difficulties are considered to be one of the more commonly reported deficits following mild head injury in both adults and children (Boll, 1983; Gronwall, 1991). While precise definitions of attention vary, it is generally accepted that the concept refers to a number of functions essential for the effective regulation of cognitive activities. Thus, the prospect of attentional problems after early mild head injury is important. In addition, attention deficits have been associated with diminished academic outcomes in children within the general population (de Jong, 1993; Fergusson & Horwood, 1992; Fowler & Cross, 1986; McKinney, 1989). Unfortunately, as Yeates (2000) points out, "... studies using objective measures of attention are relatively limited, and no studies have provided a comprehensive assessment of attention based on current theoretical models" (p.100). Both of these shortcomings may contribute to the mixed outcomes that have been reported. For example, while the four studies reviewed below use similar methods to assess aspects of attention, the findings are conflicting. However, each of the studies has focused on a narrow range of attentional processes making it difficult to draw any definitive conclusions regarding the range, or even the presence, of possible deficits in attention following mild head injury.

Robin, Max, Stierwalt, Guenzer and Lindgren (1999: *29*) reported evidence of deficits in sustained attention when measured two years after experiencing a head injury for children aged between 6-16 years. Sixty four children were included in this study; 28 of these had experienced a mild head injury, 21 a severe head injury and 15 an orthopaedic injury. Children who had experienced an orthopaedic injury were used as controls and were selected to be within the age range of the head injured children. Severity of the head injury was based on the lowest post resuscitation GCS score with mild being classified as a GCS of between 13 and 15 and severe as a GCS of between 3 and 8. A computer generated continuous performance task was used to measure sustained attention. The task involved 200 trials and took between 7 and 12 minutes to complete. The 200 trials were divided into blocks of 50 trials each to examine vigilance decrement. While there was no change across time for orthopaedic control children, the mild head injury group were reported to have demonstrated a mild vigilance decrement. Children in the severe head injury group performed significantly more poorly than both those in the mild head injury and orthopaedic groups. Given the time post-injury and the relatively short duration of the task, the presence of even a mild deficit may have potential implications for the long term cognitive functioning of children following mild head injury.

Dennis et al. (1995: *17*) also reported a variety of attentional difficulties in a group of 83 children with mild through to severe injury, defined as a blow to the head of sufficient severity to warrant hospital admission, GCS range 3-15. The children were assessed on average three and one half years after injury. Using the Gordon Diagnostic System, a portable electronic device which generates attentional tasks, children were tested for deficits in focused attention, selective attention and response modulation. The head injured children showed evidence of poor performance on measures of selective and focused attention and poor response modulation. A composite score on the tasks was generated to give an indication of overall test performance. A rating at, or above, the 26th age percentile on all three attentional tasks was used to indicate intact performance while a rating below the 26th percentile on one of the attentional tasks was taken to indicated impairment. Only 3.8% of the head injured children were rated as intact on this basis. These effects were reported to be unrelated to initial severity as rated by the GCS.

By contrast, two studies (Kaufmann, Fletcher, Levin, Miner and Ewing-Cobbs (1993: *44*; Asarnow et al., 1995: *32*) reported a lack of evidence for attention deficits in children with mild to severe head injuries when tested six months after injury. Kaufmann et al. (1993) examined outcomes for 36 children between the ages of 7 and 16. Loss of consciousness for less than 15 minutes, GCS of 13-15, no evidence of intracranial lesion on computer tomographic (CT) scan and no acute neurological deficit were the criteria used to define the 11 children in the mild injury group. GCS of 9-12 and less than, or equal 8, were used to define the 13 children in the moderate group and 12 children in the severe injury group respectively. A computer generated continuous performance task and the WISC-R Digit sub test were used to measure attention. While the severe head injury group demonstrated evidence of impaired attention on the continuous performance task, children in the mild and moderate groups were reported as performing at an average level for children of their age. Injury severity was reported to have no effect on WISC-R digit span scores, supporting the initial assertion by Kaufmann et al. (1993) that this test lacked sensitivity for detecting deficits in attention following head injury. The general findings by Kaufmann et al. (1993) are supported by Asarnow et al. (1995) who reported a lack of deficits for children on measures of selective and sustained attention when compared to other injury and non injury controls.

1.3.3 Memory Outcomes

Memory is considered a crucial aspect of cognitive functioning and is usually considered a multidimensional process subserved by various distributed neural pathways in the brain. As with attention, studies which have evaluated memory outcomes following mild head injury in childhood have not used measures that assess all aspects of memory. To date there are only 4 studies whose primary focus has been on memory as an outcome for children. Despite using similar measures of memory, findings have been conflicting with two of the four studies reviewed reporting adverse outcomes following mild head injury and two reporting no evidence of deficits.

No evidence of deficits were reported by both Levin, Eisenberg, Wigg and Kobayashi (1982: *48*) and Hannay and Levin (1989: *42*). Levin et al. (1982) examined outcomes for 60 children and adolescents following head injury. Fifteen children and 15 adolescents were classified as having either a mild to moderate injury, GCS greater than 8, and 15 children and 15 adolescents were classified as severe with a GCS less than or equal to eight. Memory ability was tested after resolution of PTA and, for those who had experienced a severe injury, again at a later time varying between 1-52 months post-injury. For those who had experienced a mild head injury the second test was administered approximately 2 months following injury. Two types of memory test were used to assess outcomes. A selective reminding test to assess verbal memory and a visual recognition test to assess non verbal memory. The verbal memory test involved 12 words presented orally over 8 trials. After each attempted recall of the entire list, subjects were reminded of only omitted words. The visual recognition memory task required the head injured child to distinguish between recurring pictures and distracter pictures. Scores for the mild to moderate group were in the average range for both verbal memory and non verbal memory when compared to normative data collected from a random selection of same age school children. For subjects with severe head injury, the children, but not adolescents, showed deficits in recognition memory. The lack of memory problems following mild head injury reported by Levin et al. (1982) was supported by Hannay and Levin (1989: *42*). The Hannay and Levin (1989) study comprised 91 adolescents aged between 13-19 years with varying degrees of head injury severity, 33 mild with GCS 13-15, 17 moderate with GCS 9-12 and 41 severe with a GCS of less than, or equal to 8. While 42% of those with severe head injury exhibited a residual deficit using a continuous recognition memory test, the mild head injured group and the uninjured control group (n = 46) showed no adverse effects.

In contrast, two studies reported deficits in memory following mild head injury (Ewing-Cobbs, Levin, Fletcher, Miner & Eisenberg, 1990: *36*; Mattson, Levin, Evankovich, Ewing-Cobbs & Fletcher, 1990: *51*). Ewing-Cobbs et al. (1990) reported evidence of memory deficits following mild head injury in a group of children selected from a paediatric hospital. Twenty one of the children were classified as mild (PTA of less than 7 days), 7 classified as moderate (PTA 8-14 days) and 9 classified as severe (PTA greater than 14 days). Verbal and non verbal memory tests similar to those used by Levin et al. (1982) were used to measure outcomes at three time periods, after resolution of PTA, at 6 months and again at 12 months post-injury. Performance for children in the mild group was within normal limits for verbal test. However, there was evidence of deficits on non verbal tasks at baseline with improvement evident by 12 months post-injury. An adverse finding for memory was also reported by Mattson et al. (1990). Mild head injury was defined as a GCS of 13 or greater without focal lesions or any evidence of upper extremity injury. As with the previous studies, verbal and non verbal memory tasks were used to assess memory deficits. A non injured control group of 32 children was used for comparison. Deficits on both verbal and non verbal tests were evident at base line in the mild head injury group. This difference was no longer evident in the younger children at either the 6 or 12 month follow up, but persistent deficits in tasks of recognition memory were still evident in the older children (10-15 years of age) at both time periods.

Levin et al. (1988) states that verbal and non verbal memory skills develop during different periods. Thus, while visual memory is established early in life, verbal memory skills are undergoing rapid development during the period of adolescence. Therefore, age at assessment will play a major role in the identification of any memory difficulties following mild head injury in children. Also, as verbal memory skills are are in the process of development during adolescents, longer periods of follow-up may be required for deficits to manifest. Both of these factors may contribute to the conflicting findings in this area.

1.3.4 Psychiatric Outcomes

Diagnosis of a psychiatric disorder is usually made in accordance with a diagnostic system, such as the DSM-IV, in which certain rules define intensity and duration of various behaviours required for a diagnosis. Childhood disorders which meet these criteria can be considered extreme forms of behavioural disorders. Diagnoses such as Attention Deficit Hyperactivity Disorder (ADHD) and Conduct Disorder/Oppositional Defiant Disorder (CD/ODD) are increasingly considered as possible outcomes following severe head injury in childhood. For example, Gerring et al. (2000) reported an increase in diagnosis of ADHD among children, 6-17 years at the time of their injury, who had experienced moderate to severe head injuries. To date, only a few studies have examined Attention Deficit Hyperactivity Disorder and CD/ODD as a possible outcomes in relation mild head injury. However, as is the case with all other outcomes associated with mild head injury in children, findings in this area are conflicting. Currently, there are no studies which have examined the possibility of psychiatric outcomes following mild head injury prior to age five, or which have had available prospectively collected information regarding the pre-injury status of the child and family (see Table 1).

The early study by Brown, Chadwick, Shaffer, Rutter & Taub (1981: *13*), which used the same subjects as Chadwick et al. (1981: *15*) described previously, reported that while over half of those in the severely head injured group developed new psychiatric disorders over a twenty seven month follow-up period, disinhibited behaviour being the most frequent, they failed to find a significant increase in new psychiatric disorders following mild head injury. Information regarding the occurrence of psychiatric disturbance following head injury was gained through parental interviews and the Conners Parental Questionnaire, which assesses emotional and behavioural disturbance, and included a measure of hyperactivity. As described previously in relation to the study undertaken by Chadwick et al. (1981), this negative result may be due to the type of control group used and the procedures employed.

In contrast, Max et al. (1998b: *24*) reported evidence of new psychiatric disorders in a group of 50 children with head injuries ranging from mild to severe. Presence of a psychiatric disorder was assessed using the Schedule for Affective Disorders and Schizophrenia for School-Age Children epidemiologic version (K-SADS-E), a Post Traumatic Stress Disorder module and the Neuropsychiatric Rating Schedule (NPRS), with play assessment being used to evaluate children under the age of six. The Diagnostic and Statistical Manual, 3rd Edition-Revised (DSM-III-R), diagnostic criteria was used with the modification that the upper age limit for onset of ADHD was dropped. The most common psychiatric disorder was ADHD, with 42% of the children reported as developing ADHD following head injury. The next most common psychiatric disorder reported by Max et al. (1998b) was CD/ODD, which 34% of the children developed following head injury. However, children who developed oppositional disorders following head injury tended to be those in the group of head injured children with the more mild injuries and also tended to have significantly more impaired family functioning with increased family histories of alcohol dependence and abuse. These authors concluded that oppositional behaviours were more likely to be related to family psychosocial adjustment problems, rather than a result of the head injury (see section 1.3.5). However, a relationship was not found for family psychosocial adjustment problems and children who developed ADHD, suggesting a stronger link between ADHD symptoms and mild head injury.

Max and colleagues, in a series of publications, have also reported evidence of a number of new psychiatric disorders in children age between 6-14 with head injuries ranging from mild to severe at follow-ups of 3, 6, 12 and 24 months post-injury (Max et al., 1997a-c, *24*). The presence of disorders in this series of studies was assessed using the same subjects and instruments as described in the previous study (Max et al., 1998a), with the addition of the Schedule for Affective Disorders and Schizophrenia for School-Age Children - Present Episode version (K-SADS-P) and sections from the K-SADS-E regarding alcohol and substance abuse. Measures were also taken regarding family psychiatric history, family functioning and socioeconomic class and measurements of intelligence. At three months 37 of the original 50 children were available for follow-up assessment, 17 of whom had developed a psychiatric disorder in the 3 months following the head injury. Disorders included organic personality syndrome, major depression, mania, simple phobia, overanxious disorder, separation anxiety disorder and obsessive-compulsive disorder. Many of the disorders had resolved by the three month follow-up.

Forty-two children, from the original study (Max et al., 1997a) were available for follow up at two years post-injury. New psychiatric disorders were reported to be present in 15 of the children, 11 of these had persisted from the previous assessments with 4 developing new disorders in the preceding 12 months. Disorders reported included simple phobia, separation anxiety, mania, organic personality syndrome, hypomania, depressed mood and marijuana dependence. Family dysfunction and pre-injury psychiatric disorders were found to be significantly related to the development of a new disorders. Max et al. (1997a-c) concluded that the onset of new psychiatric disorders following mild head injury was a rare event, but acknowledged that the findings had relied on pre-injury information regarding the child's behaviour having been collected post-injury. While the onset of new disorders in the absence of pre-injury psychiatric disorders was uncommon, the findings suggest that some children who are particularly vulnerable to increased psychiatric problems following mild head injury.

1.3.5 Behavioural Outcomes

More general adverse changes in behaviour have been a common finding following mild head injury in children, and the research in this area has covered a broad range of possible deficits. These deficits include neurobehavioural changes associated with Post Concussive Symptoms (Mittenberg, Wittner & Miller, 1997: *52*; Yeates et al., 1999: *58*), oppositional behaviour and behaviours associated with inattention, such as restlessness and hyperactivity. These behavioural outcomes following mild head injury in children are generally assessed in terms of a broad range of externalising or internalising problems which involve the ability to self regulate and inhibit behaviour, which are associated with the executive functions of the frontal lobe (Barkely, 1997). Given the relative vulnerability of the frontal lobe to damage after acceleration-deceleration impact, it should not be surprising that changes in behaviour are a common finding following mild head injury. The question of whether behavioural problems are an outcome of mild head injury has caused considerable controversy, however, and a number of studies have suggested instead that children with existing behaviour problems are more likely to suffer head injury which in turn, explains the observed differences following injury (see Table 1 for details).

As much of the research regarding behavioural outcomes has focused on behaviours which can be observed by others, the vast majority of studies have used checklists such as the Child Behaviour Check List (CBCL) to define and measure dimensions of behaviour. But the CBCL and the way information has been collected have been problematic for the assessment of behavioural outcomes following mild head injury. Relevant to the latter point is the fact that in order to determine whether any observed behavioural changes can be attributed to the injury, information regarding pre-injury behaviour is often gathered post-injury. Collection of pre-injury behaviour information has occurred at varying intervals following injury with the assumption that the information will not be biased by the child's post-injury behaviour. As stated previously, however, parents may show considerable inaccuracies when they are asked to retrospectively report aspects of their child's development. This problem may contribute to the fact that some studies report no increase in the incidence of behaviour problems among children who have suffered mild head injury (Fletcher et al., 1990: *39*; Godfrey, 1999: *4*; Kinsella, Ong, Murtagh, Prior & Sawyer, 1999: *19*; Prior et al., 1994: *54*; Knights et al., 1991: *45*), whereas other studies report the opposite. Findings from these latter studies can be divided into two groups. The first group are those which found an increase in behavioural problems and concluded that these were a result of the head injury as either no excess of pre-injury problems were detected, or those with preexisting problems had been excluded from the study (Andrews et al., 1998: *8*; Asarnow et al., 1991: *9*; Bijur et al., 1990: *11*; Greenspan & MacKenzie, 1994: *40*; Overweg-Plandsoen et al., 1999: *26*). In contrast, the second group of studies found evidence of increased behavioural disturbance among the mild head injury group, but suggested that these behaviours could be explained by preexisting problems or family factors (Casey, Ludwig & McCormack, 1986: *35*; Asarnow et al., 1995: *32*; Ponsford et al., 1999: *53*).

Three key studies will be reviewed in detail. It will be recalled that two of these, Bijur et al. (1990) and Asarnow et al. (1995), were reported by Satz et al. (1997) as being the only three studies currently available that met all six criteria essential for investigation of outcomes following mild head injury. Bijur et al. (1990) and the other study, Godfrey (1999), are the only studies that have prospectively collected pre-injury information available regarding child and family characteristics for children who had experienced head injury.

Asarnow et al.'s study (1995: *32*) was designed to overcome the important methodological problem of potential inaccuracies in pre-injury behaviour information related the time lapse between injury and information collection. Pre-injury functioning was assessed one month following injury. At this time, parents were asked to describe their child's behaviour in the six month period prior to injury. A major domain of interest was behaviour problems both for the six months prior to and 12 months following injury (as measured by the CBCL) and problems with school functioning 12 months post-injury. The authors concluded that there was no evidence of an increased rate of behaviour problems at either 1 or 12 months post-injury.

While Asarnow et al. (1995) reported no significant increases in the rate of behavioural problems in the head injury group, the authors stated, "Fundamentally different conclusions would have been reached had we not controlled for pre-injury level of functioning." Asarnow et al. (1995) found that the rate of behaviour problems collected at 12 months post-injury was reported to have declined relative to the six months prior to the index injury. This absence of an increase in behaviour problems was suggested to be inconsistent with the index injury having caused the behaviour problems. However, Patterson (1982) indicates that when parents are required to rate their child's behaviour they are relatively consistent in their bias to report improvements, even when no real changes have occurred. Thus, although Asarnow et al. (1995) endeavoured to obtain information regarding pre-injury behaviour as soon as possible following injury, it was still retrospectively derived from parental interviews and questionnaires. Therefore, it is likely that certain pre-injury behaviours were more salient to parents in the light of current behaviour. For example, Casey et al. (1986: *35*) reported that 27% of children with mild head injury demonstrated behavioural problems, by parental report, at one month post-injury. If the children in the Asarnow et al. (1995) study displayed elevated rates of behavioural problems at one month post-injury, when information regarding pre-injury behaviour was collected, the parents may have been more likely to remember these types of behaviours as also occurring more often pre-injury.

A recent study by Godfrey (1999: *4*; unavailable at the inception of this present study) reported similar findings to that of Asarnow et al. (1995), using available prospectively collected information regarding child and family characteristics. The children in this study were part of the Dunedin Multidisciplinary Health and Developmental longitudinal birth cohort. Inclusion in the mild head injury group required that the children had experienced a head injury between the ages of 7-13, with evidence of an injury to the head. Mild head injury was defined as evidence from medical records with indicated either 2 or more post concussive symptoms, loss of consciousness for less than 20 minutes, concussion or suspected concussion. In all, 38 children met the study criteria for inclusion in the mild head injury group; 126 children with fractures and 167 with no injuries were used as controls. Information regarding the childrens' premorbid behaviour, at age seven, and post-injury behaviour, at age 13, was gathered using parent and teacher forms of the Rutters child behaviour questionnaire. It was reported that the children in the head injury group were not significantly different from either of the control groups on measures premorbid or post-injury behaviour.

In contrast to the negative findings of the previous two studies, Bijur et al. (1990:*11*) found that increased behaviour problems were evident for the head injured children. Using the Rutter Child Behaviour Questionnaire and the Conners Teacher Rating Scale, it was reported that the head injured children scored higher on ratings of hyperactivity as evaluated by both parents and teachers. Whereas the parent ratings failed to reach significance, this was not the case for teacher ratings which were significant at four tenths of a standard deviation above the mean rating of the uninjured children.

All three of the studies reviewed here used children who had head injuries in the milder range and who were between five and sixteen years of age at time of injury making these studies comparable on that basis at least. Yet, findings from these studies are conflicting, two reporting no increase in behavioural difficulties following mild head injury. The increased of hyperactivity reported by teachers in the Bijur et al. (1990) study provides limited support for an increase in behavioural problems for children in this age range following mild head injury.

1.3.6 Interim Summary of Outcome Research

It is clear that there is substantial variability in findings following mild head injury in childhood. Studies have varied in terms of the outcomes examined and their definitions. As attention, behaviour and cognition are diverse concepts, they have been defined and tested in a variety of ways which may explain some of the inconsistencies in this literature. As Fletcher, Ewing-Cobbs, Francis and Levin, (1995) point out, the variability of outcomes may also be a product of the sensitivity of the measures used to assess outcome relationships. Also, there has been little consensus regarding how to interpret results, with some studies indicating other injury controls are essential while other studies have lacked controls completely. It is likely that the diversity of reported outcomes has also been contributed to by these and other methodological limitations, as well as the extant theoretical views on how results should be interpreted. These issues will be reviewed in the next section.

1.4 Methodological Issues

Conflicting data on the effects of mild head injury in children may be related to a number of methodological issues. Unfortunately, many studies in this area have suffered from poor methodology. Six areas of concern outlined by Satz et al. (1997) in their review comprised: lack of longitudinal follow up, lack of consideration for pre-injury characteristics, lack of appropriate control groups, small sample size, lack of a clear definition of mild head injury and the use of non standardised tests. Few studies have met more than four of these criteria as can be seen in Table 1. As recovery from injury must be considered in light of the developmental and maturational level of the child, one of the most compelling areas of concern is the lack of studies which have used a longitudinal design and limited research on early preschool injury. Research suggests that the structure of the human brain continues developing into adolescence (Huttenlocher, 1979), especially frontal lobe connections (Case, 1992). Thus, to investigate how a mild head injury may impact on a child's growth and development into adolescence requires attention to the types of skills that are acquired at different stages of brain maturation, extending from injury until maturation is complete. Currently held theoretical views have also influence the interpretation of research in this area. Two of the most influential theories are the expectation characteristic pattern of recovery following mild head injury, conceptualised in the dose response relationship and recovery curve, and the generally held view of greater plasticity associated with injury in younger children. These various issues are discussed in the subsequent sections.

1.4.1 Recovery Curve/Dose Response relationship

Satz et al. (1997), in their detailed review of publications produced between 1975-1995, concluded that the inconsistency of the reported findings suggest a cautious acceptance of the null hypothesis. However, the requirement of a recovery curve and a dose response relationship constitute two major assumptions that have been adopted from the work of Rutter and his colleagues and which have had a substantial impact on the interpretation of outcomes following mild head injury (Beers, 1992). As Beers (1992) points out, the studies conducted by Rutter and his colleagues were the first, largest and most frequently cited series of studies on the topic of child head injury. Rutter suggested that deficits could only be attributed to head injury if there was a progressive improvement over time following injury, a recovery curve. While this pattern of recovery may be characteristic of severe head injuries, it may be difficult to identify with the subtle improvements that might be expected following mild head injury. Further, this view assumes that the structural changes and pattern of recovery following mild head injury will be the same as those characteristically found following severe head injury. Given the different mechanisms and neuropathology involved in various severity groups (sections 1.1.3 and 1.1.4), it is likely that recovery patterns will also differ.

The second assumption adopted from Rutter's work suggests that a dose response relationship should be evident (Beers, 1992). In this way, deficits should be increasingly more evident with increasing severity of injury. Thus, if a child with a mild injury manifests a deficit of equal severity to that of a child who has suffered a severe injury, factors other than the head injury would then be assumed to have contributed to the outcome. It could be expected that the ability to detect this relationship will be directly related to the sensitivity of the measure used.

The main problem here is that number of studies have used global tests such as the WISC-R to detect deficits (Butterbaugh et al., 1993: *14*; Chadwick et al., 1981: *15*). However, global measures may fail to detect the subtle deficits that characterise mild head injuries and a number of authors have cautioned against the use of such tests as a measure of deficits following mild head injury, indicating that they lack sensitivity (Ewing-Cobbs & Fletcher, 1987; Ewing-Cobbs, Fletcher & Levin, 1986; Incagnoli, Goldstein & Golden, 1986; Lezak, 1995).

1.4.2 Age at injury

Another major assumption which has influenced the assessment of outcomes for children following head injury is the concept of better recovery, or sparing of function, as a result of greater plasticity in the immature brain. On this basis it is often considered that problems associated with childhood head injury will be of short duration and that outcomes for younger children will generally be better (Hart & Faust, 1988; Webb, Rose, Johnstone & Attree, 1996). Increased sparing in the infant is thought to occur either as a result of anatomical restructuring, or from the development of compensatory skills. The view that young children will always demonstrate greater plasticity than adults, however, is increasingly regarded as overly simplistic. Sparing and recovery after brain injury is by no means universal to all structures and many skills appear to show equal impairment regardless of the age when damage occurs (Finger & Stein, 1982; Goldman, 1974). The fact that different neural pathways in the brain develop and mature at different rates must be taken into account when evaluating outcomes in the area of mild head injury in childhood, and failure to do so may be the reason for inconsistent findings across studies. Much of the research which supports the concept of greater neural plasticity in childhood has relied on cross sectional designs. Animal studies that have examined the effects of experimental lesions in areas which are fully functional indicate that lesions to these structures produce similar effects in the infant as in the mature animal (Johnson & Almli, 1978; Goldman, 1974). It is possible that, far from a protective feature as suggested by some theorists, early head injury may result in greater deficits due to difficulties with new learning (Taylor & Alden, 1997).

1.4.3 Longitudinal research

Not only have few studies used longitudinal designs, only a small number of those studies have extended beyond five years post-injury and only one has examined adult functioning following mild head injury in childhood (see Table 1). Indeed, the early work by Kennard (1936, 1942) showed that longitudinal research is required to assess the cumulative effect and possible impact on the infant's ability to adapt to their environment after what may initially be seen as a minor impairment (Johnson & Almli, 1978; Lazar & Menaldino, 1995). Understandably, most research has relied on short periods of follow up or cross sectional design, but the age of the children investigated has varied greatly from one to fifteen years (Fletcher et al., 1996; Lyons & Matheny, 1984: *23*). Thus, these children will have differed markedly in terms of developmental level and skill acquisition at the time of testing. As Lazar and Menaldino (1995) point out, a developmental perspective with children who have suffered head injury requires a recognition of the recovery process in context of maturational and development changes.

It has been suggested that over-learned skills are less vulnerable to disruption following head injury and that skills which are in the process of being developed are most likely to reveal deficits. For example, Barnes et al. (1999: *10*) reported that reading skills in children appeared to be differentially effected depending on the age of the child at the time of injury. Fifty- five children were included in the study based on an inclusion criteria of a blow to the head of sufficient severity to warrant hospital admission. Approximately 40% of the children had a GCS of 13-15 and 40% with a GCS of less than eight. The children were divided into groups according to age. Twenty one had their injury at or before 6.5 years of age, 19 between 6.5 and 9 years and 15 who had their injury after 9 years of age. At an average of three years following injury the children were required to complete the Word Identification and Passage Comprehension sub test from the Woodcock Reading Mastery Test-Revised to assess word identification and reading comprehension skills. While children under age six appeared to have difficulty acquiring reading skills following injury, those injured between six and nine achieved better reading skills than those under six, but not as effectively as those who suffered head injury after age nine. Some of these findings were supported by Wrightson et al. (1995: *31*) who reported significant problems associated with the development of reading skills following mild head injury in a group of preschoolers. Both these studies suggest that even if the initial observable effects of mild head injury on cognitive function persist for only a short while, there may still be a long term impact depending on the developmental stage of the child at injury.

1.4.4 Pre-injury Functioning

It is evident that efforts to define outcomes following mild head injury in childhood have suffered a number of problems. One area that has received significant attention is the extent to which behavioural problems following injury can be attributed to the injury itself, rather than unrelated factors. As stated previously, a number of studies have suggested that children with behaviour problems are more likely to suffer head injury and this would explain such differences following injury. However, the available prospectively collected data using birth cohorts clearly do not support the assertion that children with behaviour disorders are more likely to suffer general injuries (Davidson, Hughs & O'Connor, 1988; Langley, Silva & Williams, 1980). Also, research which has specifically addressed the issue of increased levels of premorbid emotional behavioural problems among children who have mild head injuries, using post-injury information, have failed to find a strong association (Donders, 1992; Pelco, Sawyer, Duffield, Prior & Kinsella, 1992). Godfrey (1999: *4*), in one of only two studies which have examined the premorbid functioning of children who suffer mild head injury, reported that there were no differences between head injury children, other injury controls and no injury groups on measures of premorbid family functioning and the child's premorbid behaviour.

Premorbid Behaviour

To date only two studies have used prospectively collected data to assess the premorbid functioning of children who have experienced a head injury. To address this problem most studies have relied on scales such as the Child Behaviour Checklist (CBCL) to determine the existence of behaviour problems both pre and post-injury. Tests such as the CBCL have some advantages, because they are standardised and rate behaviour based on the previous six months, enabling a baseline for pre-injury behaviour to be collected post-injury. However, the CBCL is a broad based screening device designed to detect psychopathology, and may miss the subtle behavioural changes that might be expected following mild head injury (Cantwell; 1996; Perrin, Stein & Drotar, 1991; Reitman, Hummel, Franz & Gross, 1998). Further, repeated administration of this instrument over short time periods may distort findings as scores tend to decrease due to practice effects, giving the appearance of improvement (Milich, Roberts, Loney & Caputo, 1980). Also, the use of the CBCL in this situation relies on the parent's recall not being biased by the child's existing behaviours following the accident. As mentioned earlier, research suggests that this assumption is incorrect (McGraw & Molloy, 1941; Chess, et al., 1966).

Family Functioning

When head injury results in a particular deficit, it is difficult in the absence of accurate pre-injury information to identify the extent to which family functioning may be one major influence on symptom intensity and duration. Family stress and functioning has been identified by a number of studies as playing an important role in the onset and duration of behavioural disorders (Casey et al., 1986: *35*; Kinsella et al., 1999: *19*; Max et al., 1998b: *24*; Ponsford et al., 1999: *53*;

Rivara et al., 1994). However, measures of family functioning vary widely and, in all but two studies (Bijur et al., 1990; Godfrey, 1999), these have been collected after the child has suffered the injury. As a result, retrospective recall may have been influenced by the stress associated with having an injured child. Perhaps a more important point is that most studies have not excluded prior mild head injury from their samples. As there is a high incidence of repeat head injury, a number of families may have been accommodating the needs of a head injured family member for some time prior to the index injury. These considerations serve to highlight the need for prospective longitudinal studies to enable the inclusion of accurate and unbiased relevant information collected prior to injury.

1.4.5 Other Injury controls

Satz et al. (1997) asserted that it is essential to have an appropriate 'other injury' control group to control for possible confounds such as distress caused by general trauma. However, there are a number of reasons that make it uncertain whether an 'other injury' group is a valid control for mild head injury. Recent research has often attempted to match children with mild head injury with 'other injury' controls who have orthopaedic injuries, lacerations or burns. When matching of this type is done outcomes for mild head injury are often found to be non significant (Asarnow et a., 1995; Bijur et al., 1990). However, Beers (1992) points out that the other injury controls are matched with the head injury group by level of severity, not cause of trauma. It could be argued that injuries such as burns from a house fire or orthopaedic injury from a car accident would result in more distress than a playground fall resulting in a head injury, but all could be classified as mild injuries. Further, although children with mild head injury frequently have no overt signs of trauma, this is not true for a child with a fractured bone or burns. These types of injuries will be clearly visible for some time after hospitalisation and often require ongoing intervention as well as a change in daily living activities until the injury resolves. In other words, the mild head injury group and the other injury groups may have unequal levels of trauma that may confound measures of outcome.

1.4.6 Definitions of Mild Head Injury

The definition of mild head injury is arguably one of the most troublesome issues in this area of research. It is not surprising that definitions vary widely over different studies because they may include the use of the Glasgow Coma Scale (GCS), PTA, Length of unconsciousness, length of hospital stay, International Statistical Classification of Diseases, Injuries and Causes of Death

(ICD), electroencephalogram (EEG), AIS and combinations of these (Asarnow et al., 1995: *32*; Bijur et al., 1990: *11*; Chadwick et al., 1981: *15*; Gulbrandsen, 1984: *41*; Kinsella et al., 1999: *19*; Leathem & Body, 1997: *60*; Tompkins et al., 1990: *56*; Wrightson et al., 1995: *31*); see Table 1. Three of the most commonly used criteria are the GCS, measures of the length of PTA, and concussion.

The GCS measures the length and depth of altered consciousness by the use of three graded categories. The total of the categories gives a rating of between 3, which indicates a total lack of responsiveness, to 15, indicating a return to normal consciousness (Teasdale & Jennett, 1974). Although the GCS has been widely used it has limited utility in the accurate identification of mild as opposed to more severe head injury. For example, while the GCS provides an objective measure which can be used to accurately describe the duration of coma, most people presenting with mild head injuries are conscious by the time of admission (Lustig & Tompkins, 1998). Further, the GCS on admission is usually used as the indicator of severity in which case ratings of severity will rely on how quickly or slowly a person is admitted to hospital. Also, the use of the GCS with young children has been criticised as potentially over estimating the severity of injury in pre verbal children (Fletcher et al., 1995). In addition to the problems of using the GCS as an accurate indicator of severity for mild head injury in children, research that has used GCS definitions has used varying ratings from as low as eight to a rating of thirteen to fifteen (Levin et al., 1982: *48*; Yeates, Blumenstein, Patterson & Delis, 1995: *58*). Thus, it is evident that a diverse range of outcomes would be expected in studies where definition of severity has been based on the GCS.

Post-traumatic amnesia refers to the length of time between the head injury and the return of continuous memory. The use of PTA to define head injury severity in children is far more subjective than the GCS, relying on the accuracy of information gathered retrospectively, usually over relatively short periods of time. This calls into question the use of this measure with young children who may have difficulty either verbalising or accurately remembering the information required. As with research using the GCS, there is a diverse range of PTA criteria determining injury severity. These PTA criteria have varied from periods ranging from 5 minutes to less than seven days (Chadwick et al., 1981: *15*; Ewing-Cobbs et al., 1990: *36*; Leathem & Body, 1997: *60*). The diversity of PTA criteria and definitions of mild head injury are likely to affect the consistency of findings in these reports.

Concussion symptoms have also been used to classify the severity of injury. Although exact definitions vary, concussion is generally considered to involve an immediate alteration in consciousness at the time of the traumatic event. Concussion may occur with or without a brief period of loss of consciousness (LOC), usually less than 30 minutes, in addition to a variety of other symptoms including dizziness, nausea, amnesia, headache and vomiting. As can be seen in Table 1, length of unconsciousness and the number of concussive symptoms required for a classification of mild head injury has varied widely. However, this method of classification has a major advantage over both GCS and PTA in that it involves symptoms which are more easily understood by even very young children, making retrospective reporting of symptoms more accurate.

Despite the difficulties associated with the measures of head injury severity that are currently available, and the considerable variation used to define mild head injury, most studies define an upper limit for the mild head injury criteria. In contrast, very few studies define a lower limit. As Kibby and Long (1996) indicate, the lack of a lower limit and the wide range of upper limits defined may result in a group of individuals comprised of subjects who have not suffered a head injury at all, those with mild head injury and others with a moderate head injury, all classified as having suffered a mild head injury.

It is clear that problems with definition have contributed to the variability of outcomes and also limit the extent to which comparisons of outcomes across studies can be made. However, this problem is likely to continue in this area of research as mild head injury lacks a universally accepted definition. Also, definitions for mild head injury have changed over time. For example, Chadwick et al. (1981: *15*) used a PTA of greater than 1 hour but less than seven days, to define mild head injury, but in a more recent study Leathem and Body (1997: *60*), used greater than 5 minutes and less 1 hour. Further, as research in the area is quasi experimental in design, definitions of a particular study will be substantially limited by those used by the health care facilities from which the subjects are drawn. Also, while the use of a longitudinal design enables identification of deficits which may manifest over time, definitions are limited to those in use at the time of the study's inception.

1.5 Interim Summary

Mild head injury occurs more frequently than any other injury in childhood. While most observable effects are usually transient, research from animal studies and imaging techniques indicate that a number of structural changes occur in the brain that may have longer term consequences for the head-injured child. Therefore, further research is warranted to determine potential negative outcomes associated with these changes. The preceding review outlined a variety of possible outcomes following mild head injury in childhood that have been studied using cognitive, psychiatric and behavioural outcome variables. However, the findings of some studies have reported adverse outcomes following mild head injury in childhood while others have not. One reason for the inconsistency in findings may actually be the diverse range of outcomes that have been evaluated. Cognition, attention and behaviour are extremely broad domains and many different aspects of each have been examined. However, it is also likely that methodological difficulties and a number of currently held theoretical views have had a substantial impact on the findings in investigations of childhood head injury.

Two widely held assumptions, the idea that a recovery curve should be present and that a dose response effect should be evident, have had a substantial impact on the interpretation of results and have contributed to the inconsistency of findings. A number of authors have suggested that a recovery curve should be evident if deficits are to be attributed to the presence of head injury. As a result, in cases where deficits have been detected, but where there has been a lack of a evidence of recovery, the deficit has been attributed to preexisting problems. However, there is currently no evidence to support the notion that recovery process following mild injury will be the same as those seen following more severe injuries. The expectation of a dose response effect assumes that deficits will be increasingly pronounced with increasing severity of injury. If this was accurate, the ability to detect the dose response relationship would rely on the sensitivity of the measure used to assess the deficit. Yet, as stated previously, the measures used to define deficits following head injury in childhood have varied widely and some studies have used only broad screening measures which have been criticised as being too gross to detect subtle changes.

Research suggests that a longitudinal design is essential to fully appreciate the potential problems that may result from early mild injury. It is notable that only one study has followed to adulthood children who have suffered mild head injury, which suggested that a number of residual problems may endure. A related issue is that researchers have evaluated children over a wide age range without regard to the differential impact that head injury may have on skill acquisition and consolidation at their differing stages of development. Issues regarding age at injury are further compounded by the fact that only 7 studies have followed the children five years or more post-injury to examine whether deficits become evident later in life.

As Table 1 shows, behavioural problems have been frequently reported following childhood head injury. In the absence of pre-injury information, it is difficult to assess whether existing behavioural or other problems result in risk taking behaviours leading to injury, or whether the behaviours are a result of the head injury itself. Indeed, it has been argued that children who suffer head injuries are more likely to have had problems prior to injury. However, this assertion has relied on retrospective information which has been collected at varying intervals following injury and assumes that parents are able to report details of their child's past behaviour without being biased by the child's current behaviour. Research suggests that both these assumptions are incorrect. Not only are parents inaccurate when asked to recall aspects of their child's development, they also tend reconstruct information in the light of current events. The detection of behavioural problems has relied on checklists such as the CBCL, but it has been pointed out that these broad screening measures are not designed to detect the more subtle changes that would be expected following mild head injury. It has also been suggested that family functioning may influence onset and duration of behavioural or psychiatric difficulties following head injury, but once again the lack of prospectively collected data make this finding problematic.

These difficulties are further compounded by the generally accepted view that another injury group is an appropriate control for mild head injury. It has been suggested that in order to control for preexisting problems and stress caused by the mild head injury event, other injury controls are essential. A number of positive findings have been rejected on the basis of this assumption as the observed deficits were not significant when compared with the other injury group. However, it is doubtful whether the stress associated with injuries such as burns, lacerations or fractures, which require frequent follow-up appointments and are associated with ongoing pain, represent a suitable control for children with mild head injury.

One of the most problematic areas and possibly the most difficult to rectify is that of classification. There is currently no widely accepted definition of mild head injury and as a consequence, studies have varied widely in their criteria. This variation makes it difficult to compare findings across studies and may account for a substantial portion of the mixed outcomes in the area of childhood head injury. Further, while many studies have used the GCS and PTA to define severity, their utility for defining mild head injury in children is questionable. Classification is likely to continue to be problematic as research is limited by the availability of subjects and longitudinal studies are limited to measures of classification used when the study began.

1.6 The Current Study

The purpose of this present study was to investigate some of the long term outcomes of mild head injury experienced during childhood. The data in the study were collected from subjects who were part of a longitudinal birth cohort of 1265 children born in the Christchurch (New Zealand) urban region during mid 1977. The availability of information taken from this cohort provided several methodological advantages and a fully prospective design for the evaluation of the effects of mild head injury in childhood. The use of a cohort also meant that a large non-injured reference group was available, against which comparisons with the head injured children could be made.

The lack of a clear definition has been a major area of difficulty with research on mild head injury in children. Failure to provide both upper and lower inclusion criteria has resulted in a wide variation of head injury severity within groups classified as mild. In the current study children were selected for the injury group on the basis of information collected from both parents and hospital records. A lower criterion was set to exclude superficial injuries to the head in that the injury was required to be of sufficient severity for medical attention to be sought and to warrant a diagnosis of concussion, or suspected concussion. A clear upper limit was also imposed to ensure the inclusion of only mild injuries. Further, children were excluded from the head injury groups if they had obvious neurological difficulties prior to head injury.

As outcomes have been found to differ depending on the age and developmental level of the child at the time of the mild head injury event, children in this study were examined as a group which included all children who had a mild head injury between 0 and 10 years and in two age ranges corresponding to their age at injury, 6-10 years and 0-5 years. It was expected that children who were younger at the time of their injury would have consolidated fewer skills and may, therefore, be more likely to demonstrate deficits over time as compared to those head injured later in childhood. It has also been suggested that outcomes should be increasingly more apparent with increasing severity of injury, a dose response effect. As there was no direct information available on head injury severity, mild head-injured cases were sub-divided on the basis of whether the injury was sufficient to require outpatient or inpatient treatment.

Much of the research to date has been limited by small sample size. The use of a large birth cohort such as the one in this present study not only provided a reasonable number of children who have been identified as suffering mild head injury, but also an excellent reference group against which outcomes could be compared. Such an appropriate reference group overcomes many of the problems associated with other injury control groups because it provides a representative sample of children of similar age, education and social circumstances to those in the mild head injury group, without the possible confounding factors associated with another injury group.

While a number of studies have failed to find evidence of cognitive deficits following mild head injury, the majority of these studies have only had follow up periods of less than five years. It has been suggested that as children are in the process of development, subtle skill deficits may be masked and, thus, not become evident for some time following the injury. As the current study is longitudinal in design, it was possible to follow the children for up to sixteen years post-injury. This enabled the sampling of measures after maturation and skill development were substantially completed. In addition to the use of the WISC-R, which provided an indication of global ability, other measures of cognition were available for analysis including a variety of tests designed to tap into specific skills, such as reading and mathematics.

Changes in behaviour and attention as an outcome of mild head injury in childhood have often been investigated. However, like other areas, these findings remain inconclusive with some studies finding evidence for deficits in behaviour and attention while others have not. In order to evaluate attention and behaviour, a number of past studies have relied solely on parental reports which may be distorted as a result of the stress associated with having a child injured. In contrast, data in this study has also been collected from the children's teachers, plus both teacher and parent ratings were available up to 12 years post-injury (well past the "stress" period of mild head injury). It was expected that children in the mild head injury group would demonstrate higher levels of problem behaviours. Information on conduct and attention were collected at yearly intervals between the ages of 7 and 13 years using a combination of the Rutters and Conners child behaviour scales (Fergusson, Horwood & Lloyd, 1991). Variations of this measure have been found to be sensitive to the effects of mild head injury in previous research (Bijur et., 1990).

Recent research has also suggested that more severe behavioural problems that meet the criteria for ADHD and CD/ODD may be associated with mild head injury in childhood (Max et al., 1998b) although other studies have failed to support this finding (Brown et al., 1981). Current literature has also examined a number of other psychiatric conditions in relation to mild head injury. Findings suggest that the onset of new disorders are related to head injury severity, previous psychiatric conditions and family functioning. But again, these latter findings have relied on information gathered retrospectively. Information regarding the presence of ADHD and CD/ODD, mood disorders, alcohol abuse/dependence, substance abuse/dependence and anxiety disorders were collected in the current sample when the children were between the ages of 14 and 16 years using the DSM III-R criteria, and multiple informant data to confirm diagnosis.

As stated earlier, a major problem with the majority of studies conducted to date is the general absence of any other information (e.g., pre-injury; child and family). While a number of studies have suggested that children who suffer mild head injury are already inherently different from children who do not, information regarding differences has generally relied on potentially inaccurate retrospective information. In contrast, the children in this cohort have been studied at birth, 4 months and at annual intervals. Thus, a wide range of prospectively collected information on pre-injury factors, including measures of child behaviour and attention and family characteristics, were available for comparisons to be made regarding both pre and post-injury functioning. It was expected that the children in this study would not differ from the reference group in terms of premorbid characteristics.

Thus, the Christchurch Health and Development Study data base has provided a unique opportunity to look at a number of potential outcomes and address some of the difficulties in existing research. As outlined above, a number of previous methodological difficulties have been addressed in the design of this study, including prospectively collected pre and post-injury information on child and family characteristics, the use of a longitudinal design, a large and appropriate reference group, and the use of a large head injury sample. Together, these features provide a unique and methodologically strong study.

2. 1 Method

2.1.1 Subjects

Subjects were part of the Christchurch Health and Development study, a longitudinal study of a birth cohort born in 1977. The initial cohort of 1265 children included all those born in any hospital in the Christchurch urban region during the period of April 15th 1977 to August 5th 1977. The children have been studied at birth, 4 months, 1 year and at annual intervals until age 16 years. Information regarding injury events was gathered from parents during the annual interviews and where possible, was verified through medical records.

The aim of this present study was to examine the long term cognitive and behavioural outcomes of mild head injury in childhood. To assess this, all the children in the cohort were assigned to one of two groups, a mild head injury group or a reference group. All the children who did not meet the criteria for mild head injury and who had not suffered a moderate or severe head injury between the ages of 0 and 10 were included in the reference group. No other exclusions were used for the reference group, which varied from 670 to 830 individuals depending on which variable was assessed and missing data.

Participants were included in the mild head injury group if they had a reported head injury between the ages of 0 to 10 for which medical attention was sought and a diagnosis of concussion or suspected concussion was given.

Mild head injury was further defined by:

1. Loss of consciousness less than 20 minutes.
2. Hospitalisation of equal to or less than two days.
3. No evidence of skull fractures.

Children were required to meet all of the criteria for inclusion in the study. Children were excluded from the mild head injury group if there was evidence of premorbid neurological impairment. Of the 133 children who met the mild head injury criteria, one was excluded as there was evidence of neurological impairment that had preceded the injury, leaving 132 children eligible for inclusion in the mild head injury group.

2.1.2 Mild Head Injury Subgroups

The children who met the criteria for mild head injury were divided into two groups, inpatient and outpatient, according to the initial severity of their injury. The inpatient group (group Inpat) comprised of all children who had been admitted to hospital, for less than two days, as a result of the mild head injury. The outpatient group (group Outpat) included all of the children who, as a result of a mild head injury, had been seen by a general practitioner or in an accident and emergency department and sent home. Thirty-six children had sustained an injury of sufficient severity to warrant admission to hospital and were included in the inpatient mild injury group. Ninety-six children were included in the outpatient mild injury group. In the few cases where a child experienced multiple head injuries (group Inpat = 7, group Outpat = 13), the most severe injury was used to assign injury group.

Children were further divided according to the age at which the injury occurred. Initial analyses included all the children who had head injury between the ages of 0 and 10 comparing the three main grouping levels, reference group, outpatient group and inpatient group. Subsequent analyses included all children who had experienced their first mild head injury between 6-10 years of age and, separately, those who had experienced their first mild head injury from 0-5 years of age. For these subsequent analyses children were excluded from the 6-10 injury group if they had a head injury between ages 0-5 and excluded from the 0-5 injury group if they had a head injury between 6-10. Thus, six groupings of the head injured children were available for analysis: inpatient 0-10 and outpatient 0-10, inpatient 6-10, outpatient 6-10, inpatient 0-5, outpatient 0-5. This treatment of the sample meant that outcomes could be analysed by age at injury and by severity.

The distribution of male and female varied depending on the age of the child at the time of injury (of the 156 head injury events, 20 children had multiple injuries accounting for 44 injury events). One hundred and two injury events were reported between the ages of 0 and 5, of these 51% were male. As can be seen in Figure 1, the relative distribution of male to female injuries increased dramatically after age five, with males in the 6-10 old group accounting for 70% of the 54 injury events.

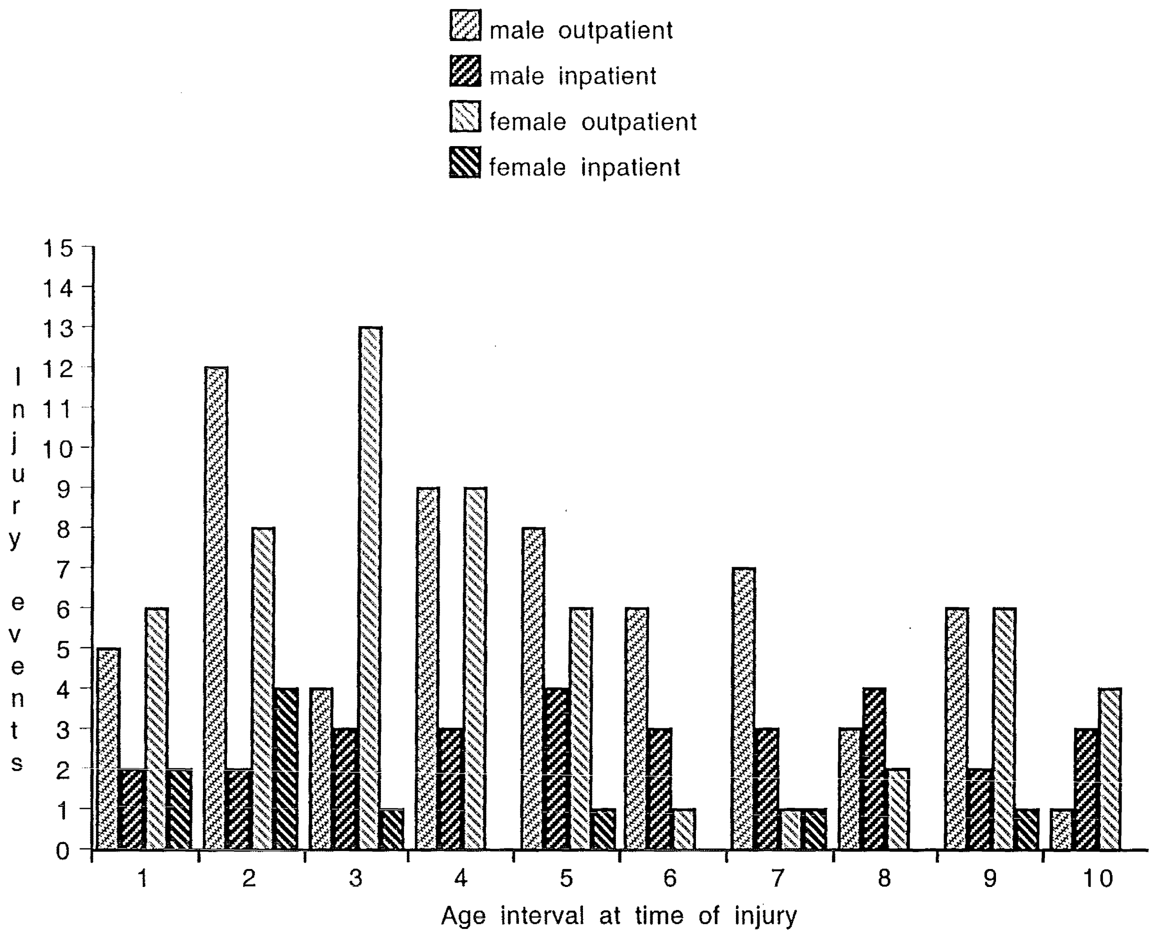

Figure 1. Yearly rate of head injury events by severity level and gender.
Note: some events represent a repeat injury (44/156)

2.1.3 Mode of injury

Information regarding mode of injury was available for all of the children who had required inpatient care. In all these cases injury resulted from an acceleration/deceleration event with 75% (27/36) being the result of falls, 8.3% (3/36) hit by an object, 5.5% (2/36) passenger in a vehicle, 2.7% (1/36) collision with a stationary object, 2.7% (1/36) fall from a bike, 5.5% (2/36) cause of injury not specified. While all hospital records were available for children who had required inpatient care, the majority of children who received out patient care had been seen by general practitioner and records were not available for these cases.

Information on the children regarding both premorbid and post-injury functioning had been collected from a wide range of sources including self report, parental interview, teacher report, standardised testing and medical records.

2.1.4 Procedure

Assessment of outcomes

The study was designed to examine the extent to which mild head injury in childhood was associated with a number of outcome variables during mid to late childhood and adolescence after controlling for potentially confounding factors. The measures described here have formed the basis of numerous publications regarding outcomes for this cohort and further details regarding different measures and procedures used may be gained from these publications (Fergusson & Horwood, 1993; Fergusson, Horwood & Lloyd, 1991; Fergusson, Horwood & Lynskey, 1993; Fergusson, Lynsky & Horwood, 1996; Horwood & Fergusson, 1998)

One question was whether children who sustained a mild head injury would show cognitive deficits when compared to children in the reference group. The dependent variables used to assess cognitive deficits were: the WISC-R, used to assess global intellectual functioning for the children who had sustained an injury before five years of age; two measures of reading ability, the Burt Word Reading Test and a measure of reading comprehension based on the Progressive Achievement Test of Reading Comprehension; and mathematical reasoning, based on the Progressive Achievement Test of Mathematics and School Certificate.

Another issue was whether there would be evidence of greater behavioural difficulties for children in the mild head injury groups in comparison to the reference group. The dependent variables used to assess behaviour were the parent and teacher ratings of conduct and attention. These were assessed yearly from the age of seven using a combination of behaviour rating scales developed by Rutter and Conners. Psychiatric disorders were evaluated by assessing the number of children who met the DSM-III-R criteria for ADHD, CD/ODD, substance abuse/dependence, alcohol abuse/dependence, mood disorders or anxiety disorders, during adolescence over the period of 14-16 years (Fergusson, Horwood & Lynskey, 1993).

It was expected that cognitive deficits, problem behaviours and psychiatric disorders might be more evident in children who had sustained an injury earlier in life. Deficits were expected to be especially apparent in those who had injuries that had required a brief period of hospitalisation, the inpatient group, this being in keeping with a dose response effect.

2.1.5 Cognitive Outcomes

The Wechsler Intelligence Scale for Children - Revised (WISC-R)

Global cognitive functioning was assessed when the children were 8 years old using the WISC-R. Information from this test was analysed for children in the reference group and those children in the mild head injury groups who had sustained their injury before the age of five. The WISC-R is an individually administered intelligence test suitable for children 6 years of age to 16 years 11 months (Wechsler, 1974). Full scale scores were used in this analysis, which have been found to have a good reliability (alpha 0.93).

Burt Word Reading Test

Reading ability was assessed using the Burt Word Reading Test. The Burt Word Reading Test consists of 110 words graded in order of difficulty and is designed to provide a broad measure of word-reading skills among primary school children (Gilmore, Croft & Read, 1981). Scores are based on the number of words read correctly from a list. The Burt Word Reading Test has a reliability level of 0.98. Information was analysed based on test scores which were collected annually from ages 8 to 13 years for children who were injured prior to age five, and all children in the reference group. Information for children who were injured after age five were analysed for years 10 to 13 inclusive (Fergusson & Horwood, 1993).

Progressive Achievement Test

Two standardised tests of achievement were used. A test of reading achievement based on the Progressive Achievement Test of Reading Comprehension (Elley & Reid, 1969) and a test of mathematical reasoning based on the Progressive Achievement Test of Mathematics (Reid & Hughes, 1974). These tests have a reliability of 0.83 and 0.87, respectively. The test of reading achievement was administered to all the children when they were 10 years of age and again at 12 years of age. The mathematical reasoning test was administered during the intervening year when the children were 11 years of age (Horwood & Fergusson, 1998).

School Certificate

School certificate is a national series of examinations that New Zealand children may undertake at the end of the 5th year of post primary education when the children are between 15 and 16 years of age. School Certificate examinations are graded from A to E, with a pass in a subject area being regarded as a grade of either A, B or C (Horwood & Fergusson, 1998).

2.1.6 Behavioural Outcomes

Attention / Conduct

Information regarding inattention / hyperactivity and conduct-disordered behaviour was collected from two sources, mothers and teachers, on a yearly basis from the ages of 7 to 13 years (inclusive). A combined version of the Rutter (Rutter, Tizard & Whitmore, 1970) and Conners (Conners, 1969; Conners, 1970) maternal report questionnaires was used to gather information from mothers regarding their child's behaviour. A parallel teacher version was used by the child's teacher to assess behaviour at school. Items were selected from the original questionnaires to conform to the DSM-III (Fergusson, Horwood & Lloyd, 1991). The resulting scales have been found to have good reliability with coefficient alpha values ranging from 0.82 to 0.93 (Fergusson, Lynskey & Horwood, 1996; Fergusson et al., 1997). For the main analyses, scores for all age groups were analysed for years 10 to 13 inclusive, and in addition, for children who were injured prior to age five scores were analysed for years 7 to 9 and 7 to 13 (inclusive) using repeated measures.

2.1.7 Psychiatric Outcomes

Measures were chosen to provide sufficient information suitable for a DSM-III-R classification of ADHD and CD/ODD as detailed below. Information was gathered from all children using both mother report and self report over the period of 14 to 16 years. Interviews were conducted with the child and the mother at different sites (mothers at home and children at school) and by two different interviewers. To determine whether the DSM-III-R criteria for ADHD/CD were met, a combination of the scores from the parental and self report report measures were used (Fergusson, Horwood & Lynskey, 1993).

(a) Self report information for ADHD was gathered using the Diagnostic Interview Schedule for Children (DISC) (Costello, Edelbrock, Kalas, Kessler & Kalaric, 1982) and supplemented by additional items to meet DSM-III-R Criteria. The Self-Report Early Delinquency (SRED) scale was used to assess conduct disorder (Moffitt & Silva, 1988).

(b) Maternal report of ADHD was measured using the Revised Behaviour Problems

Checklist (RBPC) (Quay & Petersen, 1987). As the RBPC contained only 11 items corresponding to the 14 symptoms listed in the DSM-III-R for ADHD, children were classified as as having met the criteria for ADHD if the mother reported severe expression on at least six of the 11 ADHD symptoms. Conduct disorder was measured using a parent version of the SRED (Fergusson, Horwood & Lynskey, 1993).

As with ADHD and CD/ODD, measures of mood, anxiety, alcohol abuse/dependence and substance abuse/dependence were gathered over the period from 14 to 16 years of age and are based on a combination of parental and self report measures.

Anxiety disorders (overanxious disorder, separation anxiety, simple phobia and social phobia) and mood disorders (major depression current and past year, and dysthymia) were obtained over the period 14-16 years from child interviews using an abbreviated version of the Diagnostic Interview Schedule for Children (DISC) (Costello et al., 1982) and supplemented with items related to generalised anxiety from the Diagnostic Interview Schedule (DIS). Additional items were included to meet the DSM-III-R criteria. Information was obtained from mothers using parent version of DISC supplemented with items from the DIS. A combination of parent and child information was used to assign DSM-III-R criteria. Disorders were coded as either present or absent (Fergusson, Horwood & Lynskey, 1993).

Information regarding substance abuse/dependence behaviours (tobacco and illicit drug abuse) and alcohol abuse/dependence was obtained over the period of 14-16 years from the child using survey questions regarding their use of these substances and related matters and supplemented by the Rutgers Alcohol Problems Index (White & Labouvie, 1989). Parental report was obtained from questions regarding the parent's perceptions and knowledge of their child's use of these substances (Fergusson, Horwood & Lynskey, 1993).

The presence of alcohol or substance abuse or dependence according to the DSM-III-R criteria was based on a combination of parent and child information. If the mother or child reported the use of 5 or more cigarettes a day and the experience of two or more symptoms of dependence, including trying to quit but being unable to, feeling tense or irritable if unable to get a cigarette or unable to go one day without smoking, the criterion for nicotine dependence was considered to have been met. A report of two problems from the Rutgers Alcohol Problem Index (White & Labouvie, 1989) by the child or parent report of significant problems on survey items regarding alcohol use or abuse behaviours, were used to define alcohol use or abuse. Other substance abuse (most common was cannabis abuse) was defined as the child having used the substance on at least 5 occasions and the report of the substance leading to at least one of the following problems: missing school, getting into trouble with parents of friends, getting poorer grades at school, getting into trouble at school or with the police, being unable to remember things, getting into fights or having health problems. Disorders were coded as either present or absent (Fergusson, Horwood & Lynskey, 1993).

2.1.8 Potential Confounding Factors

Family and Personal Characteristics

To assess the extent to which associations between mild head injury and a number of cognitive and behavioural outcomes could be explained by the characteristics of the child and family, factors which are known, or suspected, to be associated with the outcomes of interest were included in the analysis. The relationship between head injury group membership and these factors was evaluated after assessing the influence of head injury status on any outcome. Non-head injury factors were then applied in analyses of covariance and logistic regression analyses. As detailed below, family characteristics were assessed using measures of socioeconomic status, maternal attributes, mother and child interactions, family exposure to adverse life events and measures of family stability. Child characteristics were assessed using measures of maternal reports of child rearing difficulties and birth characteristics of the child.

A. 1 Mother and Child Characteristics

Two aspects of early mother and child interactions, maternal emotional responsiveness and maternal punitiveness, were assessed by direct observation when the child was three years of age. Maternal emotional responsiveness assessed the degree to which the mother responded in a free and open way with the child, while maternal punitiveness assessed the extent to which the mother avoided the use of punitive or restrictive child rearing practices. Measures were based on the maternal emotional responsive and avoidance of punishment and restriction scale of the HOME inventory (Bradley & Caldwell, 1977; Elardo, Bradley & Caldwell, 1977).

A. 2 Demographic factors

(1) The child's birth weight
(2) Gender of the child
(3) Mother's age at the time of the child's birth.
(4) Maternal education at the time of the child's birth. Education at the time of the child's birth was coded in three levels: 1 = no formal educational qualification; 2 = secondary qualifications; 3 = tertiary qualifications.

A. 3 Child-rearing difficulties

Parental reports of child-rearing difficulties were obtained at years two, three, four and five of the study. Information was gathered during interviews with the mother and used an open ended questioning method based on a checklist of behaviours which occur commonly in preschool children. Mothers were asked during each interview period to indicate if their child displayed any of the following behaviours: 1. difficulty in management or control (including disobedience, wilfulness or stubbornness); 2. temper tantrums or breath-holding episodes; 3. aggressive behaviour (e.g., bullying other children). Behaviours were coded as either present or absent for each of the three areas (Beautrais, Fergusson & Shannon, 1982).

B. 1 Measures of Family Characteristics

Socioeconomic status (SES) of the family was assessed at the time of the child's birth. Families' SES was based on the Elley/Irving scale of SES for New Zealand families (Elley & Irving, 1976) and coded using three levels: 1 = professional/managerial; 2 = clerical, technical, skilled; 3 = semiskilled, unskilled, unemployed (Horwood & Fergusson, 1998).

An additional measure of family living standards was also available. This was based on interviewers ratings of the family living standard which were collected yearly from 1-10 years. Ratings were made on a 5 point scale with 1 = very good and 5 = very poor. These yearly ratings were averaged over the 10 years and multiplied by 10 to give a score of between 10 = very good to 50 = very poor, as a global measure of family living standards over the 10 year period (Horwood & Fergusson, 1998).

B. 2 Family Exposure to Adverse Life Events

Information regarding adverse life events was collected on an annual basis from the second to the tenth year of age (inclusive). The family exposure to adverse life events was assessed using a 20 item checklist based on a modified version of the Holmes and Rahe Social Readjustment Rating Scale (Holmes & Rahe, 1967). Scores reflected a count of the number of adverse life events that occurred to the family during the year. (Beautrais et al., 1982). Information regarding adverse life events was summarised over two time periods, 2-5 years and 6-10 years.

B. 3 Measures of Family Stability

The number of parental changes experienced by the child as a result of either parental separation, parental reconciliation following separation ,or entry of a step parent (legal or de facto) into the family, were used to measure family stability. Information regarding parental changes was collected yearly and summarised over two time periods, 0-5 years and 6-10 years (Beautrais et al., 1982).

3. 1 Results

3.1.1 Design and Statistical Considerations

The major focus of this study was to examine outcomes following a mild head injury in childhood. The research hypothesis was that head injured children would demonstrate higher levels of behaviour problems, as measured by parent and teacher ratings of attention and conduct. It was further predicted that greater numbers of children who experienced mild head injury would demonstrate behaviours consistent with a DSM-III-R criteria as measured by both parent and child report. In addition, it was expected that deficits on measures of cognitive and academic performance would be evident. As described previously, the cohort was divided into two mild head injury groups and a reference group. The two mild head injury groups were identified on the basis of a medical diagnosis of severity as reflected by inpatient care (Inpat) or not (Outpat). Additional analyses were conducted on the basis of age at injury, using the developmental periods of 6-10 and 0-5 to define the age at injury. Mainly for reasons of clarity of evaluation and reporting, these two periods for age at injury were analysed separately, rather than as an additional factor. There were also several measures which, because of age constraints, were valid for the younger age group only. In all reported results, the reference group acted as a comparison for those children in the mild head injury groups. As shown in the subsequent tables, numbers varied depending on missing data.

The initial analyses examined the magnitude of effects of head injury status on measures of behavioural, psychiatric and cognitive outcomes. However, current literature suggests that a number of characteristics of the child and family will influence outcomes following mild head injury and could be potential confounds. Therefore, the second part of the analysis was to examine the relationship between head injury status and associated variables of child and family characteristics that could be potential confounds (section 3.1.2) prior to the main analyses. The final and main analyses evaluated the strength of the association between head injury and behaviour, psychiatric and cognitive functioning. Measures of family and personal characteristics, that were known to be related, or thought to be related, to these potential outcomes were used as covariates in ANCOVAS and logistic regression analyses. The use of covariates in the analyses enabled an assessment of the strength of association between head injury and behavioural psychiatric and cognitive outcomes, after adjustment for any potential confounds.

3.1.2 Selection of Potential Confounds

To explore the potential influence of family and personal characteristics on outcomes, any variable that was related to head injury group membership was selected as a covariate. To err on the side of a cautious inclusion of any potential confound a lenient significance criterion, ($p < 0.10$) was used in the selection of these variables. The relationship between family and individual characteristics was obtained using a non-parametric test (Kruskal-Wallis) for non-normally distributed variables, and an ANOVA test for variables which were considered to be normally distributed. As shown in Table 3, eight variables were selected in this manner for the 0-10 year head injury group, which included: 1. number of adverse life events experienced by the family when the child was between 1-5 years of age; 2. the number of adverse life events experienced by the family when the child was between 6-10 years of age; 3. maternal responsiveness towards the child at age 3; 4. maternal punitiveness at age 3; 5. number of parental changes due to the entry of a step parent into the family when the child was between 6-10 years; 6. number of changes experienced by the child as a result of parental separations when the child was between between 6-10 years; 7. management problems between 2 -5; 8. aggressive behaviour between 2-5. Again, to err on the side of explicitly ruling out the influence of potential confounds in the current analyses, four additional variables, collected at the time of the child's birth, were also added to the covariate list: 1. mother's age; 2. child's birth weight; 3. mother's educational level; 4. soico economic status of the family (see Table 3, 4 and 5). Using these covariates, adjusted values (means, odds-ratios) were generated for each outcome variable. This adjusted value may be interpreted as the hypothetical value when the effects of family and personal factors have been taken into account.

3.1.3 Statistical Analyses for Cognitive and Behavioural Outcomes

The initial analysis for continuously scored variables measuring behaviour and cognitive outcomes, used a 3 (head injury status: reference, outpat, inpat) x 2 (gender) analysis of variance (ANOVA) to compare the unadjusted means between the groups for each outcome variable. Gender was used as a factor in the initial analysis for all the children in the 0-10 year group and the 0-5 year sub group. The 6-10 year subgroups were not analysed in this way as only one female was available for analysis in the outpatient group. Although there were clear gender effects on a number of the outcome variables, no gender x group interactions were present (all $p > 0.10$) on any outcome variable, hence gender was excluded from subsequent analyses.

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Table 3. Family and personal characteristics of the sample, 0-10 injury group

Characteristic		Reference {n}		[SD]	Outpatient {n}		[SD]	Inpatient {n}		[SD]	p-level
Family Exposure to Adverse Life Events, mean over years 0-5		{958}	2.02	[1.30]	{92}	2.29	[1.30]	{33}	2.73	[1.40]	<.00*
Family Exposure to Adverse Life Events, mean over years 6-10		{914}	2.51	[1.60]	{86}	3.00	[1.80]	{33}	3.33	[1.30]	<.00*
Mean Mothers Age at birth of Child		{1068}	26.0	[5.00]	{96}	25.4	[4.70]	{36}	24.9	[4.80]	<.28
Mean Birth Weight of Child (Kg)		{1065}	3.36	[0.53]	{96}	3.39	[0.53]	{36}	3.28	[0.54]	<.58
Maternal Emotional Re-sponsiveness at age 3	mean	{1018}	8.14	[1.70]	{94}	8.47	[1.40]	{36}	7.89	[2.00]	<.13
	median	{1018}	9.00		{94}	9.00		{36}	8.00		<.11
Maternal Punitiveness assessed at age 3	mean	{1018}	0.84	[0.80]	{94}	1.10	[0.96]	{36}	1.03	[1.10]	<.01*
	median	{1018}	1.00		{94}	1.00		{36}	1.00		<.03*
Step Parent Changes 0-5 yr		{78}	7.3%		{8}	8.3%		{5}	13.9%		<.30
Step Parent Changes 6-10 yr		{76}	7.1%		{13}	13.5%		{2}	5.6%		<.07
Parental Separations 0-5 yr		{136}	12.7%		{14}	14.6%		{6}	16.7%		<.64
Parental Separations 6-10 yr		{139}	13.0%		{17}	17.7%		{12}	33.3%		<.00*
Parental Reconciliations 0-5 yr		{52}	4.9%		{5}	5.2%		{4}	11.1%		<.26
Parental Reconciliations 6-10 yr		{58}	5.4%		{6}	6.2%		{3}	8.3%		<.75
Mothers Education at time of Child's Birth	No Formal	{531}	49.7%		{54}	56.2%		{20}	55.6%		<.23
	Secondary	{323}	30.2%		{27}	28.1%		{13}	36.1%		
	Tertiary	{214}	20.0%		{15}	15.6%		{3}	8.3%		
Parental Report of Difficult to Manage Child between ages 2-5		{395}	41.2%		{48}	52.2%		{20}	60.6%		<.02*
Parental Report of Child Aggression between ages 2-5		{319}	33.3%		{43}	46.7%		{13}	39.4%		<.06
Socioeconomic Status of the Family at time of Child's Birth	Semi Skilled	{287}	26.9%		{19}	19.8%		{6}	16.7%		<.25
	Skilled	{562}	52.6%		{53}	55.2%		{24}	66.7%		
	Professional	{219}	20.5%		{24}	25.0%		{6}	16.7%		
Family Status at time of child's birth	Single Parent	{74}	6.9%		{8}	8.3%		{4}	11.1%		<.57
	Two Parent	{994}	93.1%		{88}	91.7%		{32}	88.9%		
Child's Birth Order In The Family	First	{409}	38.3%		{34}	35.4%		{14}	38.9%		<.67
	Second	{377}	35.3%		{44}	45.8%		{8}	22.2%		
	Third	{195}	18.3%		{15}	15.6%		{11}	30.6%		
	Fourth	{59}	5.5%		{0}	0.0%		{2}	5.6%		
	Fifth	{28}	2.6%		{3}	3.1%		{1}	2.8%		
Global Family Living Standard		{1068}	28.6	[4.62]	{96}	28.5	[5.10]	{36}	29.2	[4.56]	<.65

* Significant effect

Table 4. Family and personal characteristics of the sample, 6-10 injury group

		Reference			Outpatient			Inpatient			
Characteristic		{n}		[SD]	{n}		[SD]	{n}		[SD]	p-level
Family Exposure to Adverse Life Events, mean over years 0-5		{952}	2.03	[1.30]	{29}	2.33	[1.00]	{10}	2.83	[1.50]	<.09
Family Exposure to Adverse Life Events, mean over years 6-10		{914}	2.51	[1.60]	{27}	2.80	[1.30]	{11}	3.76	[0.90]	<.02*
Mean Mothers Age at birth of Child		{1005}	25.9	[4.90]	{31}	25.0	[4.90]	{13}	24.3	[3.20]	<.31
Mean Birth Weight of Child (Kg)		{1002}	3.36	[0.53]	{31}	3.34	[0.56]	{13}	3.4	[0.53]	<.96
Maternal Emotional Re-sponsiveness at age 3	mean	{982}	8.29	[1.50]	{30}	8.20	[1.70]	{13}	7.00	[2.50]	<.01*
	median	{982}	9.00		{30}	9.00		{13}	8.00		<.08
Maternal Punitiveness assessed at age 3	mean	{982}	0.86	[0.81]	{30}	0.80	[0.66]	{13}	1.00	[1.20]	<.76
	median	{982}	1.00		{30}	1.00		{13}	1.00		<.98
Step Parent Changes 0-5 yr		{78}	7.8%		{3}	9.7%		{2}	15.4%		<.53
Step Parent Changes 6-10 yr		{76}	7.6%		{4}	12.9%		{1}	7.7%		<.56
Parental Separations 0-5 yr		{136}	13.5%		{6}	19.4%		{2}	15.4%		<.61
Parental Separations 6-10 yr		{139}	13.8%		{5}	16.1%		{5}	38.5%		<.06
Parental Reconciliations 0-5 yr		{52}	5.2%		{2}	6.5%		{1}	7.7%		<.89
Parental Reconciliations 6-10 yr		{58}	5.8%		{1}	3.2%		{1}	7.7%		<.80
Mothers Education at time of Child's Birth	No Formal	{500}	49.8%		{16}	51.6%		{9}	69.2%		<.22
	Secondary	{301}	30.0%		{9}	29.0%		{4}	30.8%		
	Tertiary	{204}	20.3%		{6}	19.4%		{0}	0.0%		
Parental Report of Difficult to Manage Child between ages 2-5		{393}	41.3%		{15}	51.7%		{7}	60.0%		<.28
Parental Report of Child Aggression between ages 2-5		{317}	33.3%		{11}	37.9%		{4}	40.0%		<.64
Socioeconomic Status of the Family at time of Child's Birth	Semi Skilled	{262}	26.1%		{6}	19.4%		{3}	23.1%		<.59
	Skilled	{540}	53.7%		{17}	54.8%		{7}	53.8%		
	Professional	{203}	20.2%		{8}	25.8%		{3}	23.1%		
Family Status at time of child's birth	Single Parent	{67}	6.7%		{4}	12.9%		{1}	7.7%		<.40
	Two Parent	{938}	93.3%		{27}	87.1%		{12}	92.3%		
Child's Birth Order In The Family	First	{388}	38.6%		{13}	41.9%		{5}	38.5%		<.54
	Second	{352}	35.0%		{14}	45.2%		{3}	23.1%		
	Third	{186}	18.5%		{3}	9.7%		{5}	38.5%		
	Fourth	{55}	5.5%		{0}	0.0%		{0}	0.0%		
	Fifth	{24}	2.4%		{1}	3.2%		{0}	0.0%		
Global Family Living Standard		{1005}	28.6	[4.54]	{31}	28.7	[4.59]	{13}	27.9	[4.05]	<.89

* Significant effect

Table 5. Family and personal characteristics of the sample, 0-5 injury group

Characteristic		Reference {n}		[SD]	Outpatient {n}		[SD]	Inpatient {n}		[SD]	p-level
Family Exposure to Adverse Life Events, mean over years 0-5		{958}	2.02	[1.30]	{59}	2.31	[1.50]	{21}	2.76	[1.40]	<.02*
Family Exposure to Adverse Life Events, mean over years 6-10		{912}	2.51	[1.60]	{55}	3.13	[2.10]	{20}	3.28	[1.50]	<.01*
Mean Mothers Age at birth of Child		{1064}	25.9	[5.00]	{61}	25.6	[4.70]	{21}	25.1	[5.70]	<.65
Mean Birth Weight of Child (Kg)		{1061}	3.36	[0.53]	{61}	3.42	[0.54]	{21}	3.22	[0.57]	<.35
Maternal Emotional Responsiveness at age 3	mean	{1018}	8.14	[1.70]	{60}	8.58	[1.30]	{21}	8.29	[1.40]	<.14
	median	{1018}	9.00		{60}	9.00		{21}	8.00		<.11
Maternal Punitiveness assessed at age 3	mean	{1018}	0.84	[0.80]	{60}	1.25	[1.10]	{21}	1.09	[1.00]	<.00*
	median	{1018}	1.00		{60}	1.00		{21}	1.00		<.01*
Step Parent Changes 0-5 yr		{78}	7.3%		{5}	8.2%		{3}	14.3%		<.46
Step Parent Changes 6-10 yr		{76}	7.1%		{9}	14.8%		{1}	4.8%		<.08
Parental Separations 0-5 yr		{136}	12.8%		{7}	11.5%		{4}	19.0%		<.69
Parental Separations 6-10 yr		{138}	13.0%		{12}	19.7%		{7}	33.3%		<.01*
Parental Reconciliations 0-5 yr		{52}	4.9%		{3}	4.9%		{3}	14.3%		<.17
Parental Reconciliations 6-10 yr		{58}	5.5%		{5}	8.2%		{2}	9.5%		<.51
Mothers Education at time of Child's Birth	No Formal	{530}	49.8%		{36}	59.0%		{11}	52.4%		<.22
	Secondary	{320}	30.1%		{17}	27.9%		{9}	42.9%		
	Tertiary	{214}	20.1%		{8}	13.1%		{1}	4.8%		
Parental Report of Difficult to Manage Child between ages 2-5		{395}	41.2%		{31}	52.5%		{13}	61.9%		<.03*
Parental Report of Child Aggression between ages 2-5		{319}	33.3%		{32}	54.2%		{8}	38.1%		<.01*
Socioeconomic Status of the Family at time of Child's Birth	Semi Skilled	{287}	27.0%		{13}	21.3%		{3}	14.3%		<.69
	Skilled	{559}	52.5%		{35}	57.4%		{15}	71.4%		
	Professional	{218}	20.5%		{13}	21.3%		{3}	14.3%		
Family Status at time of child's birth	Single Parent	{74}	7.0%		{4}	6.6%		{3}	14.3%		<.43
	Two Parent	{990}	93.0%		{57}	93.4%		{18}	85.7%		
Child's Birth Order In The Family	First	{407}	38.3%		{20}	32.8%		{9}	42.9%		<.93
	Second	{375}	35.2%		{27}	44.3%		{4}	19.0%		
	Third	{195}	18.3%		{12}	19.7%		{5}	23.8%		
	Fourth	{59}	5.5%		{0}	0.0%		{2}	9.5%		
	Fifth	{28}	2.6%		{2}	3.3%		{1}	4.8%		
Global Family Living Standard		{1064}	28.6	[4.62]	{61}	28.6	[5.43]	{21}	30.1	[4.92]	<.28

* Significant effect

The principal analyses examined behavioural and cognitive outcomes using an analysis of covariance (ANCOVA). Where relevant repeated measures across years were used to compare groups based on an adjusted means using the covariates as identified above, to evaluate changes that may occur across time. For the main analyses, repeated measures were averaged across four years (10-13). As additional post-injury information was available for the children injured between 0-5 years, repeated measures were also used across 3 (7-9 years), and 7 (7-13 years) years. For clarity, any effects related to these repeated measures are reported separately in section (3.2.4)

Post-hoc Scheffé tests for all pair-wise comparisons were used to test the differences between groups where appropriate. The Scheffé test was used as the most conservative means to evaluate pair-wise comparisons (Howell, 1997), given the controversy surrounding the effects of early mild head injury.

3.1.4. Statistical Analyses for Psychiatric Outcomes

Dichotomously scored outcome variables such as ADHD, CD/ODD, mood disorders, anxiety disorders, substance abuse/dependence and alcohol abuse/dependence were analysed using logistic regression models. These analyses generate tests of relative beta weights (ß) and give the relative likelihood (odds ratio) of any given dichotomous outcome. Adjusted and unadjusted ratios were analysed wherever possible using the same covariates, as indicated previously. Overall significance of the head injury effect on outcomes was tested by a three step process: 1. outcome variable, inpatient and outpatient groups and covariates were entered into the logistic regression model; 2. outcome variable and covariates were fitted to the model without inpatient and outpatient groups; 3. significance of the head injury after adjustment was tested by analysing the difference between the chi square values and degrees of freedom obtained in steps 1 and 2. Due to properties of the data, missing combinations of some variables meant that it was not possible to analyse effects using all the covariates. Therefore, each model was built sequentially to include as many covariates as possible in any give analysis. Birth weight was not included in any of these analyses. In the analyses of conduct disorder, substance abuse/dependence and alcohol abuse/dependence for the 6-10 year subgroup, ADHD and alcohol abuse/dependence for the 0-5 subgroup, the logistic regression model would accept a limited number of covariates.

3.2.1 Analyses of Outcomes for Children injured between 0-10 years

Analyses of Unadjusted Means for Behavioural outcomes 0-10 year group.

The unadjusted mean ratings of attention for each group (reference [no injury]; Outpatient; Inpatient) averaged over years 0-10 of age are shown on the the left hand side of Table 6. Measures are provided in terms of mothers ratings, teacher ratings and a combined score. A head injury status main effect was evident for mothers, $F(2, 909) = 3.28, p < 0.04$, MSE = 26, and combined ratings, $F(2, 887) = 3.43, p < 0.03$ MSE = 20.1, but just failed to reach significance for teachers ratings, $F(2, 887) = 2.92, p < 0.06$, MSE = 26.9. Post-hoc Scheffé tests of the unadjusted means confirmed that mother, teacher and combined ratings for the Inpatient 0-10 group were higher than those of both the reference (all $p < 0.001$) and outpatient groups ($p < 0.004$, $p < 0.007$, $p < 0.004$, respectively); the later two groups showed similar mean ratings.

Similar outcomes were apparent for mean ratings of conduct averaged over 10-13 years of age (left side of Table 6). A head injury status main effect was evident for mother, $F(2, 909) = 3.68$, $p < 0.03$, MSE = 91.51, teacher, $F(2, 887) = 3.70, p < 0.03$, MSE = 96.0, and combined ratings of conduct, $F(2, 887) = 4.85, p < 0.01$, MSE, 71.6. Post-hoc Scheffé tests confirmed that teacher and combined mother and teacher ratings for the inpatient group were higher than those of both the reference (both $p < 0.001$, and outpatient group ($p < 0.009$, $p < 0.016$, respectively). For mothers, ratings of conduct Inpatient group differs only from the reference group ($p < 0.004$). Again, the outpatient and reference groups showed similar mean ratings.

Analyses of Adjusted Means for 0-10 year group.

The adjusted mean ratings of attention for each group (reference [no injury], outpatient, inpatient) averaged over 10-13 years of age, are shown on the right hand side of Table 6. After controlling for potential confounds a main effect for head injury status was evident for mother, $F(2, 900) = 5.01, p < 0.01$, MSE = 23.0, teacher, $F(2, 878) = 5.40, p < 0.01$, MSE = 26.7 and combined ratings of attention, $F(2, 878) = 5.25, p < 0.01$, MSE = 18.1. Post-hoc Scheffé tests confirmed that scores of attention for the Inpatient 0-10 group were higher on mother, teacher and combined ratings, than both the reference (all $p < 0.001$) and the outpatient group ($p < 0.001$, $p < 0.003$, $p < 0.001$, respectively); the latter two groups showed similar mean ratings.

Mean ratings of conduct averaged over 10-13 years of age, are also shown on the right hand side of Table 6. A head injury status main effect was evident for teachers ratings of conduct, F (2,

878) = 5.59, $p < 0.00$, MSE = 86.8, and combined ratings of conduct, $F(2, 878) = 4.84$, $p < 0.01$, MSE = 57.1. Post-hoc Scheffé tests confirmed that teacher and combined ratings were higher for the Inpatient 0-10 group than those of the reference (both $p < 0.001$) and outpatient group (both $p < 0.004$). Mothers ratings of conduct were not significant.

Analyses of Unadjusted/Adjusted Means of Cognitive outcomes for 0-10 year group.

As is shown on the bottom of Table 6, none of the variables used to test cognitive and academic outcomes were significant for the 0-10 year group for either adjusted or unadjusted means.

Effect sizes for Behavioural and Cognitive Outcomes

Effect sizes for behavioural and cognitive outcomes, both adjusted and unadjusted are shown on Table 7 and will be commented on in the discussion.

Analyses of Psychiatric outcomes for 0-10 year group.

Percentages of children who met the criteria for a DSM-III- R diagnoses of a psychiatric disorder are displayed on Table 8. Overall group differences did not reach significance for ADHD, (df (2) chi square = 3.38) CD/ODD, (df (2) chi square = 3.70) presence of mood disorders, (df (2) chi square = 1.10) anxiety disorders, (df (2) chi square = 0.77) alcohol abuse/ dependence, (df (2) chi square = 0.60) or substance abuse/dependence, (df (2) chi square = 4.83). However, unadjusted Odds Ratio (OR) for ADHD, (Inpat, OR = 3.83, $p < 0.01$, Outpat, OR = 1.92, $p < 0.11$) CD/ODD, (Inpat, OR = 3.11, $p < 0.02$, Outpat, OR = 0.91, $p < 0.83$) and substance abuse/dependence (Inpat, OR = 4.88, $p < 0.01$, Outpat, OR = 1.52, $p < 0.45$) indicated that children in 0-10 year inpatient group, but not the outpatient group, had a higher likelihood of developing these disorders when compared with the reference group (see left hand side of Table 9).

Adjusted odds ratios are shown on the right hand side of Table 9. Initial findings are weakened when the covariates are added, but remain significant on substance abuse/dependence for children in the inpatient group (Inpat, OR 4.63, $p < 0.02$, Outpat, OR = 1.27, $p < 0.67$). A trend towards significance is evident for the inpatient group on ADHD, (Inpat, OR = 2.93, $p <$ 0.06, Outpat, OR = 1.42, $p < 0.44$) CD/ODD (Inpat, OR 2.93, $p < 0.07$, Outpat, OR = 0.70,

text continued on page 79

Table 6. Head injury status 0-10 years of age at injury

	Unadjusted Means								Adjusted Means §							
	Reference		Outpatient		Inpatient				Reference		Outpatient		Inpatient			
	{n=}	Mean [SD]	{n=}	Mean [SD]	{n=}	Mean [SD]	F	p-level	{n=}	Mean [SD]	{n=}	Mean [SD]	{n=}	Mean [SD]	F	p-level
Attention and Conduct ratings average outcome averaged over years 10-13																
Attention																
Mothers	{807}	10.10 [2.6]	{80}	10.13 [2.5]	{28}	12.07 [3.8]†∫	3.28	<.04*	{807}	10.44 [2.6]	{80}	10.10 [2.5]	{28}	11.76 [3.8]†∫	5.01	<.01*
Teachers	{788}	9.44 [2.7]	{79}	9.70 [3.0]	{26}	11.65 [3.1]†∫	2.92	<.06	{788}	9.73 [2.7]	{79}	9.62 [3.0]	{26}	11.41 [3.1]†∫	5.40	<.01*
Combined	{788}	9.76 [2.3]	{79}	9.88 [2.5]	{26}	11.68 [2.6]†∫	3.43	<.03*	{788}	10.07 [2.3]	{79}	9.85 [2.5]	{26}	11.39 [2.6]†∫	5.25	<.01*
Conduct																
Mothers	{807}	28.14 [4.7]	{80}	29.13 [5.4]	{28}	31.24 [6.1]†	3.68	<.03*	{807}	28.97 [4.7]	{80}	28.99 [5.4]	{28}	30.55 [6.1]	1.93	<.14
Teachers	{789}	23.40 [4.9]	{78}	23.81 [5.5]	{26}	27.31 [6.2]†∫	3.70	<.03*	{789}	23.83 [4.9]	{78}	23.71 5.5]	{26}	26.94 [6.2]†∫	5.59	<.00*
Combined	{789}	25.77 [4.2]	{78}	26.50 [5.0]	{26}	29.34 [5.4]†∫	4.85	<.01*	{789}	26.43 [4.2]	{78}	26.39 [5.0]	{26}	28.79 [5.4]†∫	4.84	<.01*
Cognitive and academic outcomes																
BURT10-13 ^	{613}	75.80 [18.5]	{64}	75.16 [20.5]	{21}	71.97 [18.1]	0.41	<.66	{613}	74.71 [18.5]	{64}	74.12 [20.5]	{21}	71.18 [18.1]	0.42	<.65
SchoolCert	{787}	3.35 [2.2]	{80}	3.33 [2.4]	{26}	2.42 [2.3]	2.45	<.09	{787}	3.15 [2.2]	{80}	3.31 [2.4]	{26}	2.63 [2.3]	1.16	<.30
PAT10 ‡	{695}	10.48 [7.0]	{70}	10.60 [7.9]	{24}	8.46 [6.9]	0.37	<.69	{695}	10.01 [7.0]	{70}	10.59 [7.9]	{24}	8.94 [6.9]	0.58	<.55
PAT11 ~	{679}	25.14 [7.3]	{67}	25.26 [8.2]	{22}	22.09 [7.1]	1.25	<.28	{679}	24.75 [7.3]	{67}	25.19 [8.2]	{22}	22.56 [7.1]	1.23	<.29
PAT12 ‡	{655}	12.97 [4.8]	{66}	13.24 [4.6]	{23}	12.26 [5.4]	0.20	<.81	{655}	12.56 [4.8]	{66}	13.19 [4.6]	{23}	12.72 [5.4]	0.58	<.56

* Significant effect across 3 groups

§ Mean adjusted for parental report of management difficulties and aggression, measures of maternal emotional responsiveness and punitiveness, stress, parental changes, family exposure to adverse life events 1-10 years, child's birth weight, maternal age, maternal education and socioeconomic status.

† Significantly different from reference group, Scheffé test.

∫ Significantly different from inpatient group, Scheffé test

^ Average score on Burt Word Reading Test over ages 10-13.

‡ Scores on reading comprehension at ages 10 & 12, derived from Progressive Achievement Test.

~ Scores on mathematics achievement at ages 11, derived from Progressive Achievement Test.

Table 7. Head injury outcome effect size, 0-10 years of age at injury

	Unadjusted Means				Adjusted Means			
	Effect Size				Effect Size			
	Cohen's d	95% CI (d) ∫	r	BESD †	Cohen's d	95% CI (d) ∫	r	BESD †
Attention ratings outcome averaged over years 10-13								
Mothers	0.743	0.365 – 1.122	0.349	32.6% – 67.5%	0.498	0.121 – 0.876	0.242	37.9% – 62.1%
Teachers	0.814	0.421 – 1.206	0.377	31.2% – 68.9%	0.619	0.227 – 1.010	0.296	35.2% – 64.8%
Combined	0.830	0.438 – 1.223	0.384	30.8% – 69.2%	0.571	0.179 – 0.963	0.245	37.8% – 62.3%
Conduct ratings outcome averaged over years 10-13								
Mothers	0.651	0.274 – 1.030	0.310	34.5% – 65.5%	0.332	-0.045 – 0.709	0.164	41.8% – 58.2%
Teachers	0.790	0.397 – 1.183	0.368	31.6% – 68.4%	0.628	0.236 – 1.020	0.300	35.0% – 65.0%
Combined	0.841	0.448 – 1.234	0.388	30.6% – 69.4%	0.556	0.164 – 0.947	0.268	36.6% – 63.4%
Cognitive and academic outcomes								
Burt10-13	0.207	-0.228 – 0.642	0.103	44.9% – 55.2%	0.191	-0.244 – 0.626	0.095	45.3% – 54.8%
SchoolCert	0.422	0.031 – 0.813	0.207	39.7% – 60.4%	0.236	-0.155 – 0.627	0.117	44.2% – 55.9%
PAT10 ‡	0.288	-0.119 – 0.696	0.143	42.9% – 57.2%	0.153	-0.254 – 0.560	0.076	46.2% – 53.8%
PAT11 ~	0.418	-0.007 – 0.843	0.205	39.8% – 60.3%	0.300	-0.125 – 0.725	0.148	42.6% – 57.4%
PAT12 ‡	0.147	-0.269 – 0.563	0.073	46.4% – 53.7%	0.033	-0.383 – 0.449	0.017	49.2% – 50.8%

‡ Scores on reading comprehension at ages 10 & 12, derived from Progressive Achievement Test.

~ Scores on mathematics achievement at ages 11, derived from Progressive Achievement Test.

∫ Confidence Interval

† Binomial Effect Size Display

Table 8. Numbers of children in each group meeting the DSM-III-R criteria for mental disorder.

	Reference			Outpatient			Inpatient		
	n total	n affected	percent	n total	n affected	percent	n total	n affected	percent
Attention Deficit Hyperactivity Disorder									
Group 0-10	859	51	5.9%	83†	8	9.6%	30†	5	16.7%
Group 6-10				28	1	3.6%	12	1	8.3%
Group 0-5				51	6	11.8%	16	4	25.0%
Conduct Disorder									
Group 0-10	859	74	8.6%	83†	6	7.2%	30†	7	23.3%
Group 6-10				28	3	10.7%	12	1	8.3%
Group 0-5				51	3	5.9%	16	6	37.5%
Mood Disorders									
Group 0-10	859	113	13.2%	83†	14	16.9%	30†	6	20.0%
Group 6-10				28	7	25.0%	12	2	16.7%
Group 0-5				51	6	11.8%	16	4	25.0%
Anxiety Disorders									
Group 0-10	859	261	30.4%	83†	21	25.3%	30†	8	26.7%
Group 6-10				28	8	28.6%	12	2	16.7%
Group 0-5				51	13	25.5%	16	6	37.5%
Substance Abuse or Dependence									
Group 0-10	859	31	3.6%	83†	4	4.8%	30†	5	16.7%
Group 6-10				28	2	7.1%	12	1	8.3%
Group 0-5				51	2	3.9%	16	4	25.0%
Alcohol Abuse or Dependence									
Group 0-10	859	90	10.5%	83†	8	9.6%	30†	5	16.7%
Group 6-10				28	2	7.1%	12	1	8.3%
Group 0-5				56	6	10.7%	12	4	33.3%

† Totals are greater than the sum of the injuries in the 6-10 and 0-5 year group because children injured across both age periods are excluded

Table 9. Odds Ratios relative to reference group for each group by age at head injury.

	Unadjusted					Adjusted §				
	Odds Ratio	95% CL ʃ	ß	t	p	Odds Ratio	95% CL ʃ	ß	t	p
Attention Deficit Hyperactivity Disorder										
Group 0–10										
Outpatient	1.92	0.87–4.25	0.65	1.62	<.11	1.42	0.58–3.48	0.35	0.78	<.44
Inpatient	3.83	1.38–10.60	1.34	2.59	<.01*	2.93	0.95–9.01	1.07	1.87	<.07
Group 6–10										
Outpatient	0.70	0.09–5.32	-0.35	-0.34	<.73	0.49	0.06–4.11	-0.72	-0.66	<.51
Inpatient	2.11	0.26–17.26	0.74	0.69	<.49	1.27	0.14–11.45	0.24	0.22	<.83
Group 0–5										
Outpatient	2.35	0.93–5.57	0.81	1.76	<.08	1.71¥	0.58–4.64	0.50	0.95	<.34
Inpatient	5.61	1.74–18.21	1.73	2.89	<.01*	4.63¥	1.21–16.98	1.52	2.26	<.03*
Conduct Disorder										
Group 0–10										
Outpatient	0.91	0.38–2.17	-0.01	-0.22	<.83	0.70	0.28–1.75	-0.36	-0.77	<.45
Inpatient	3.11	1.21–7.99	1.14	2.36	<.02*	2.48	0.92–6.68	0.91	1.80	<.08
Group 6–10										
Outpatient	1.29	0.38–4.39	0.26	0.41	<.68	1.25†	0.35–4.52	0.23	0.35	<.73
Inpatient	0.94	0.12–7.34	-0.63	-0.06	<.95	0.66†	0.08–5.38	-0.41	-0.39	<.70
Group 0–5										
Outpatient	0.71	0.21–2.35	-0.34	-0.56	<.58	0.51	0.14–1.81	-0.68	-1.05	<.29
Inpatient	6.54	2.30–18.58	1.88	3.53	<.00*	5.58	1.85–16.87	1.72	3.05	<.00*
Mood Disorders										
Group 0–10										
Outpatient	1.59	0.86–2.95	0.46	1.47	<.14	1.40	0.73–2.67	0.33	1.01	<.31
Inpatient	1.65	0.61–4.47	0.50	0.99	<.32	1.25	0.45–3.49	0.22	0.43	<.60
Group 6–10										
Outpatient	2.82	1.15–6.95	1.04	2.26	<.02*	2.58	1.03–6.47	0.95	2.02	<.04*
Inpatient	0.91	0.11–7.38	-0.10	-0.09	<.93	0.57	0.07–4.73	-0.57	-0.53	<.60
Group 0–5										
Outpatient	1.01	0.42–2.42	0.01	0.03	<.98	0.83	0.32–2.11	-0.19	-0.40	<.69
Inpatient	2.42	0.76–7.67	0.88	1.50	<.13	1.87	0.57–6.13	0.63	1.04	<.30
Anxiety Disorders										
Group 0–10										
Outpatient	0.88	0.52–1.48	-0.13	-0.45	<.63	0.80	0.43–2.51	-0.22	0.78	<.43
Inpatient	1.00	0.63–1.60	0.00	0.02	<.99	0.82	0.09–2.34	-0.19	0.44	<.66
Group 6–10										
Outpatient	1.12	0.48–2.60	0.11	0.26	<.79	1.04	0.43–2.51	0.04	0.10	<.92
Inpatient	0.68	0.14–3.31	-0.38	-0.48	<.63	0.47	0.09–2.34	-0.76	-0.93	<.35
Group 0–5										
Outpatient	0.80	0.42–1.52	0.23	-0.69	<.49	0.73¥	0.37–1.43	-0.32	-0.93	<.35
Inpatient	1.40	0.50–3.90	0.34	0.64	<.52	1.24¥	0.43–3.55	0.22	0.40	<.69

Table 9 (continued).

	Unadjusted					Adjusted §				
	Odds Ratio	95% CL ∫	ß	t	p	Odds Ratio	95% CL ∫	ß	t	p
Substance Abuse or Dependence										
Group 0–10										
Outpatient	1.52	0.52–4.46	0.42	0.76	<.45	1.27	0.42–3.94	0.24	0.42	<.67
Inpatient	4.88	1.58–15.12	1.59	2.75	<.01*	4.63	1.38–15.61	1.53	2.48	<.02*
Group 6–10										
Outpatient	2.15	0.49–9.54	0.77	1.01	<.31	1.86†	0.39–8.97	0.62	0.78	<.44
Inpatient	2.45	0.31–19.64	0.90	0.84	<.40	1.29†	0.14–11.98	0.25	0.22	<.82
Group 0–5										
Outpatient	1.19	0.28–5.19	0.18	0.24	<.81	1.10	0.24–4.88	0.07	0.09	<.93
Inpatient	9.36	2.83–30.96	2.24	3.67	<.00*	9.09	2.45–33.66	2.21	3.31	<.00*
Alcohol Abuse or Dependence										
Group 0–10										
Outpatient	0.87	0.39–1.96	-0.14	-0.34	<.73	0.78	0.34–1.79	-0.25	-0.59	<.55
Inpatient	1.53	0.52–4.55	0.43	0.77	<.44	1.29	0.42–3.98	0.26	0.45	<.65
Group 6–10										
Outpatient	0.74	0.17–3.22	-0.29	-0.40	<.69	0.66ç	0.15–2.89	-0.42	-0.56	<.58
Inpatient	0.00	–	-22.12	-0.01	<1.0	0.00ç	–	-22.60	0.00	<1.0
Group 0–5										
Outpatient	1.19	-0.71–1.06	0.18	0.39	<.69	1.07¥	0.43–2.68	0.07	0.14	<.89
Inpatient	2.98	-0.06–2.25	1.09	1.86	<.06	2.74¥	0.83–9.03	1.01	1.65	<.10

* Significant effects

§ Unless otherwise indicated, groups are adjusted for parental report of management difficulties and aggression, measures of maternal emotional responsiveness and punitiveness, stress, parental changes, mothers age, mothers education, SES and family exposure to adverse life events, 1–10.

† Group adjusted for measures of maternal emotional responsiveness and punitiveness, parental changes, mothers age, SES and mothers education.

¥ Group adjusted for parental report of management difficulties and aggression, measures of maternal emotional responsiveness and punitiveness, stress, parental changes, mothers age, mothers education, SES and family exposure to adverse life events, 1–5.

ç Group adjusted for parental report of management difficulties, measures of maternal emotional responsiveness and punitiveness, stress, parental changes, mothers age, mothers education, SES.

∫ Confidence Level

$p < 0.44$) with children in 0-10 year inpatient group, but not the outpatient group, having a higher likelihood of developing these disorders when compared with the reference group. There were no significant differences before, or after, covariates were added between inpatient and outpatient groups for mood disorders, anxiety disorders or alcohol abuse/dependence.

3.2.2 Analyses of Outcomes for Children injured between 6-10 years

Analyses of Unadjusted Means for Behavioural outcomes 6-10 year group.

Unadjusted means for children who had their first mild head injury between 6-10 years are shown on the left hand side of Table 10. Mean ratings of attention for each group (reference [no injury]; Outpatient; Inpatient) are averaged over years 10 to 13 years of age. Measures are provided in terms of mothers ratings, teacher ratings, and a combined score. A head injury status main effect was evident on teacher ratings of attention, F (2, 818) = 4.99, $p < 0.01$, MSE = 30.4, and combined ratings of attention, F (2, 818) = 4.45, $p < 0.01$, MSE = 22.20. Mothers ratings of attention were not significant. Post-hoc Scheffé tests confirmed that teacher ratings of attention for the inpatient group were higher than those of both the reference ($p < 0.007$) and outpatient group ($p < 0.032$). When mother and teacher ratings were combined, significant differences were apparent for only the inpatient group when compared to the reference group ($p < 0.014$).

Mean ratings of conduct for each group (reference [no injury]; Outpatient; Inpatient) are averaged over years 10 to 13 years of age. A head injury status main effect was evident on mother ratings of conduct, F (2, 838) = 3.78, $p < 0.02$, MSE = 91.75, and combined ratings of conduct, F (2, 818) = 3.47, $p < 0.03$, MSE = 72.82. Teachers ratings of conduct failed to reach significance. Post-hoc Scheffé tests confirmed a difference for the outpatient group when compared with the reference group for mother ratings of conduct but failed to find any pair-wise differences for combined ratings of conduct.

Analyses of Adjusted Means for Behavioural outcomes 6-10 year group.

Adjusted means for children who had their first mild head injury between 6-10 years are displayed on the right hand side of Table 10. Mothers and teachers ratings of attention are averaged over 10-13 year of age. When covariates were added a head injury status main effect was evident only on teachers ratings of attention, F (2, 806) = 3.34, $p < 0.04$, MSE = 26.3. Post- hoc Scheffé tests confirmed that teachers ratings of attention for the Inpatient 6-10 group were higher than those of both the outpatient and reference group ($p < 0.006$, $p < 0.05$).

Table 10. Head injury status 6-10 years of age at injury

	Unadjusted Means					Adjusted Means §				
	Reference	Outpatient	Inpatient			Reference	Outpatient	Inpatient		
	{n=} Mean [SD]	{n=} Mean [SD]	{n=} Mean [SD]	F	p-level	{n=} Mean [SD]	{n=} Mean [SD]	{n=} Mean [SD]	F	p-level
Attention and Conduct ratings outcome averaged over years10-13										
Attention										
Mothers	{807} 10.10 [2.6]	{25} 10.53 [2.7]	{9} 11.92 [2.2]	2.52	<.08	{807} 10.48 [2.6]	{25} 10.64 [2.7]	{9} 11.43 [2.2]	0.77	<.47
Teachers	{788} 9.44 [2.7]	{25} 9.59 [3.2]	{8} 12.53 [2.6]†∫	4.99	<.01*	{788} 9.72 [2.7]	{25} 9.73 [3.2]	{8} 12.11 [2.6]†∫	3.34	<.04*
Combined	{788} 9.76 [2.3]	{25} 10.10 [2.8]	{8} 12.20 [1.8]†	4.45	<.01*	{788} 10.10 [2.3]	{25} 10.20 [2.8]	{8} 11.72 [1.8]	2.26	<.10
Conduct										
Mothers	{807} 28.14 [4.7]	{25} 30.26 [5.6]	{9} 30.89 [6.8]	3.78	<.02*	{807} 29.10 [4.7]	{25} 30.43 [5.6]	{9} 29.76 [6.8]	1.35	<.26
Teachers	{789} 23.37 [4.9]	{25} 24.16 [5.8]	{8} 26.63 [4.0]	1.98	<.13	{789} 23.86 [4.9]	{25} 24.38 [5.8]	{8} 25.91 [4.0]	0.92	<.40
Combined	{789} 25.77 [4.2]	{25} 27.21 [5.1]	{8} 28.91 [5.3]	3.47	<.03*	{789} 26.53 [4.2]	{25} 27.44 [5.1]	{8} 27.91 [5.3]	1.23	<.30
Cognitive and academic outcomes										
BURT10-13 ^	{613} 75.86 [18.5]	{21} 72.23 [19.5]	{5} 58.30 [15.9]	2.60	<.08	{613} 75.20 [18.5]	{21} 71.50 [19.5]	{5} 59.70 [15.9]	2.35	<.10
SchoolCert	{787} 3.35 [2.2]	{25} 3.10 [2.4]	{8} 2.75 [2.5]	0.44	<.65	{787} 3.00 [2.2]	{25} 2.89 [2.4]	{8} 3.29 [2.5]	0.13	<.89
PAT10 ‡	{695} 10.48 [7.0]	{22} 11.36 [8.4]	{7} 8.29 [6.7]	0.51	<.61	{695} 10.00 [7.0]	{22} 11.05 [8.4]	{7} 9.07 [6.7]	0.35	<.71
PAT11 ~	{679} 25.14 [7.3]	{22} 24.45 [7.7]	{5} 21.20 [6.2]	0.81	<.45	{679} 24.90 [7.3]	{22} 24.39 [7.7]	{5} 21.50 [6.2]	0.66	<.52
PAT12 ‡	{655} 12.97 [4.8]	{22} 12.95 [3.9]	{6} 12.67 [5.9]	0.01	<.99	{655} 12.59 [4.8]	{22} 12.79 [3.9]	{6} 13.20 [5.9]	0.07	<.93

* Significant effect across 3 groups

§ Mean adjusted for parental report of management difficulties and aggression, measures of maternal emotional responsiveness and punitiveness, stress, parental changes, family exposure to adverse life events 1-10 years, child's birth weight, maternal age, maternal education and socioeconomic status.

† Significantly different from reference group, Scheffé test.

∫ Signficantly different from inpatient group, Scheffé test

^ Average score on Burt Word Reading Test over ages 10-13.

‡ Scores on reading comprehension at ages 10 & 12, derived from Progressive Achievement Test.

~ Scores on mathematics achievement at ages 11, derived from Progressive Achievement Test.

There were no other significant group differences for adjusted means in the 6-10 year group.

Analyses of Unadjusted/Adjusted Means of Cognitive outcomes for 6-10 year group.

As is shown on the bottom of Table 10, none of the variables used to test cognitive and academic outcomes were significant for the 6-10 year groups for either adjusted or unadjusted means.

Effect sizes for Behavioural and Cognitive Outcomes

Effect sizes for behavioural and cognitive outcomes, both adjusted and unadjusted are shown on Table 11 and will be commented on in the discussion.

Analyses of Psychiatric outcomes for 6-10 year group.

Overall group differences were not significant for, ADHD (df (2) chi square = 0.57), CD (df (2) chi square = 0.28), Mood disorders (df (2) chi square = 3.96), anxiety disorders (df (2) chi square = 2.98), substance abuse/dependence (df (2) chi square = 0.57) or Alcohol abuse/dependence (df (2) chi square = 2.69). As can be seen on the left hand side of Table 9, children in the 6-10 outpatient group had a significantly higher chance of developing a mood disorder (Inpat, OR = 0.91, $p < 0.93$, Outpat, OR = 2.84, $p < 0.02$). When odds ratios are adjusted, as shown on the right hand side of Table 9, children in the outpatient group were still more likely to show behaviours consistent with a mood disorder (Inpat, OR = 0.57, $p < 0.60$, Outpat, OR = 2.58 $p < 0.04$). Odds Ratios were not significant, before or after adjustment of means, for either the inpatient or outpatient 6-10 year group for ADHD, CD/ODD, anxiety disorders, alcohol abuse/dependence, or substance abuse/dependence (Table 9).

3.2.3 Analyses of Outcomes for Children injured between 0-5 years
Main Analyses of Unadjusted Means for Behavioural Outcomes 0-5 year group

As all the children in these groups experienced head injury prior to age five, results regarding outcomes for attention and conduct were available for analysis over a greater number of post-injury years and mean outcomes are presented over three periods, 10-13 years (to provide comparisons for the 0-10 year and 6-10 year mild head injury groups), 7-13 years and 7-9 years.

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Table 11. Head injury outcome effect size, 6-10 years of age at injury

	Unadjusted Means				Adjusted Means			
	Effect Size				Effect Size			
	Cohen's d	95% CI (d) ∫	r	BESD †	Cohen's d	95% CI (d) ∫	r	BESD †
Attention ratings outcome averaged over years 10-13								
Mothers	0.700	0.042 – 1.358	0.330	33.5% – 66.5%	0.366	-0.292 – 1.023	0.180	41.0% – 59.0%
Teachers	1.144	0.445 – 1.842	0.497	25.2% – 74.9%	0.885	0.187 – 1.582	0.405	29.8% – 70.3%
Combined	1.062	0.363 – 1.760	0.469	26.6% – 73.4%	0.705	0.008 – 1.402	0.333	33.4% – 66.6%
Conduct ratings outcome averaged over years 10-13								
Mothers	0.581	-0.076 – 1.124	0.279	36.1% – 64.0%	0.140	-0.517 – 0.797	0.070	46.5% – 53.5%
Teachers	0.666	-0.032 – 1.362	0.316	34.2% – 65.8%	0.419	-0.287 – 1.115	0.205	39.8% – 60.3%
Combined	0.745	0.048 – 1.442	0.349	32.6% – 67.5%	0.327	-0.369 – 1.024	0.161	41.9% – 58.1%
Cognitive and academic outcomes								
Burt10-13	0.949	0.067 – 1.831	0.429	28.6% – 71.5%	0.838	0.044 – 1.719	0.387	30.7% – 69.4%
SchoolCert	0.272	-0.424 – 0.969	0.135	43.3% – 56.8%	0.132	-0.828 – 0.565	0.066	46.7% – 53.3%
PAT10 ‡	0.313	-0.432 – 1.057	0.155	42.3% – 57.8%	0.133	-0.612 – 0.877	0.066	46.7% – 53.3%
PAT11 ~	0.540	-0.341 – 1.420	0.261	37.0% – 63.1%	0.466	-0.414 – 1.346	0.227	38.7% – 61.4%
PAT12 ‡	0.063	-0.742 – 0.866	0.031	48.4% – 51.6%	0.127	-0.931 – 0.677	0.063	46.9% – 53.2%

‡ Scores on reading comprehension at ages 10 & 12, derived from Progressive Achievement Test.

~ Scores on mathematics achievement at ages 11, derived from Progressive Achievement Test.

∫ Confidence Interval

† Binomial Effect Size Display

Table 12. Head injury status 0-5 years of age at injury

	Unadjusted Means					Adjusted Means §				
	Reference	Outpatient	Inpatient			Reference	Outpatient	Inpatient		
	{n=} Mean [SD]	{n=} Mean [SD]	{n=} Mean [SD]	F	p-level	{n=} Mean [SD]	{n=} Mean [SD]	{n=} Mean [SD]	F	p-level
Attention and Conduct ratings outcome averaged over years 10-13										
Attention										
Mothers	{807} 10.10 [2.6]	{51} 9.97 [2.5]	{17} 12.50 [4.5]†∫	4.15	<.02*	{807} 10.51 [2.6]	{51} 9.92 [2.5]	{17} 12.15 [4.5]†∫	5.43	<.01*
Teachers	{788} 9.44 [2.7]	{50} 9.74 [2.9]	{16} 11.58 [3.2]†	2.89	<.06	{788} 9.78 [2.7]	{50} 9.62 [2.9]	{16} 11.36 [3.2]†∫	3.1	<.05*
Combined	{788} 9.76 [2.3]	{50} 9.83 [2.4]	{16} 11.76 [2.9]†∫	3.44	<.03*	{788} 10.12 [2.3]	{50} 9.75 [2.4]	{16} 11.47 [2.9]†∫	3.86	<.03*
Conduct										
Mothers	{807} 28.14 [4.7]	{51} 28.70 [5.3]	{17} 31.91 [6.0]†	3.83	<.02*	{807} 29.36 [4.7]	{51} 28.49 [5.3]	{17} 31.19 [6.0]†∫	2.68	<.07
Teachers	{789} 23.37 [4.9]	{49} 23.75 [5.5]	{16} 28.30 [7.1]†∫	5.29	<.01*	{789} 23.95 [4.9]	{49} 23.48 [5.5]	{16} 27.99 [7.1]†∫	6.2	<.00*
Combined	{789} 25.77 [4.2]	{49} 26.25 [5.1]	{16} 30.15 [5.6]†∫	6.06	<.00*	{789} 26.53 [4.2]	{49} 26.03 [5.1]	{16} 29.61 [5.6]†∫	5.75	<.00*
Attention and Conduct ratings outcome averaged over years 7-13										
Attention										
Mothers	{807} 10.20 [2.5]	{51} 10.45 [2.4]	{17} 12.57 [4.2]†∫	4.45	<.01*	{807} 10.63 [2.5]	{51} 10.40 [2.4]	{17} 12.18 [4.2]†∫	4.27	<.02*
Teachers	{781} 9.45 [2.6]	{50} 9.95 [3.0]	{16} 11.53 [3.1]†	3.77	<.02*	{781} 9.79 [2.6]	{50} 9.83 [3.0]	{16} 11.30 [3.1]†	3.04	<.05*
Combined	{781} 9.81 [2.2]	{50} 10.18 [2.5]	{16} 11.74 [2.7]†	4.04	<.02*	{781} 10.19 [2.4]	{50} 10.11 [2.8]	{16} 11.43 [2.7]†∫	3.00	<.05*
Conduct										
Mothers	{807} 28.02 [4.3]	{51} 28.79 [4.7]	{17} 31.77 [5.7]†	4.49	<.01*	{807} 28.94 [4.3]	{51} 28.61 [4.7]	{17} 31.03 [5.7]†∫	2.93	<.06
Teachers	{782} 23.16 [4.3]	{49} 24.10 [5.5]	{16} 27.17 [6.2]†	5.50	<.01*	{782} 23.72 [4.3]	{49} 23.81 [5.5]	{16} 26.87 [6.2]†∫	4.65	<.01*
Combined	{782} 25.60 [3.8]	{49} 26.45 [4.9]	{16} 29.50 [5.4]†∫	6.91	<.00*	{782} 26.35 [3.8]	{49} 26.24 [4.9]	{16} 28.96 [5.4]†∫	5.00	<.01*
Attention and Conduct ratings outcome averaged over years 7-9										
Attention										
Mothers	{867} 10.37 [2.7]	{55} 11.17 [2.8]	{20} 12.65 [4.9]†	7.00	<.00*	{867} 10.86 [2.7]	{55} 11.09 [2.8]	{20} 12.25 [4.9]†	3.10	<.05*
Teachers	{858} 9.53 [2.8]	{55} 10.28 [3.4]	{19} 11.19 [3.4]†	4.21	<.02*	{858} 9.89 [2.8]	{55} 10.13 [3.4]	{19} 10.99 [3.4]	1.72	<.18
Combined	{858} 9.96 [2.4]	{55} 10.73 [2.8]	{19} 11.62 [2.9]†	6.01	<.00*	{858} 10.37 [2.4]	{55} 10.61 [2.8]	{19} 11.32 [2.9]	1.98	<.14

Table 12. (continued) Head injury status 0-5 years of age at injury

	Unadjusted Means											Adjusted Means §										
	Reference			Outpatient			Inpatient					Reference			Outpatient			Inpatient				
	{n=}	Mean	[SD]	{n=}	Mean	[SD]	{n=}	Mean	[SD]	F	p-level	{n=}	Mean	[SD]	{n=}	Mean	[SD]	{n=}	Mean	[SD]	F	p-level
Attention and Conduct ratings outcome averaged over years 7-9 (continued)																						
Conduct																						
Mothers	{867}	28.02	[4.5]	{55}	29.25	[4.8]	{20}	31.18	[6.7]†	5.83	<.00*	{867}	28.98	[4.5]	{55}	29.04	[4.8]	{20}	30.43	[6.7]	1.43	<.24
Teachers	{858}	22.97	[4.5]	{55}	24.35	[6.2]	{19}	25.12	[5.8]	4.00	<.20	{858}	23.52	[4.5]	{55}	24.06	[6.2]	{19}	24.86	[5.8]	1.25	<.29
Combined	{858}	25.50	[3.8]	{55}	26.80	[4.7]	{19}	28.15	[5.4]†	6.70	<.00*	{858}	26.24	[3.8]	{55}	26.55	[4.7]	{19}	27.65	[5.4]	1.89	<.16
Cognitive and academic outcomes																						
IQ age 8	{712}	102.3	[15.2]	{48}	101.2	[15.2]	{17}	95.10	[19.5]	1.60	<.21	{712}	100.9	[15.2]	{48}	101.4	17.0]	{17}	96.4	[19.5]	0.86	<.43
BURT ^	{569}	67.23	[17.9]	{41}	67.20	[17.9]	{14}	63.87	[16.6]	0.09	<.91	{569}	65.94	[17.9]	{41}	66.92	[19.8]	{14}	65.44	[16.6]	0.07	<.94
SchoolCert	{787}	3.36	[2.2]	{51}	3.47	[2.2]	{16}	2.19	[2.3]	2.56	<.08	{787}	3.14	[2.2]	{51}	3.51	[2.4]	{16}	2.36	[2.3]	2.17	<.12
PAT10 ‡	{695}	10.48	[7.0]	{47}	10.19	[7.0]	{16}	8.86	[7.4]	0.38	<.69	{695}	9.93	[7.0]	{47}	10.26	[7.8]	{16}	9.05	[7.4]	0.20	<.82
PAT11 ~	{679}	25.14	[7.3]	{44}	25.57	[7.3]	{16}	22.87	[7.5]	1.37	<.26	{679}	24.64	[7.3]	{44}	25.46	[8.6]	{16}	22.48	[7.5]	1.09	<.34
PAT12 ‡	{655}	12.97	[4.8]	{43}	13.35	[4.8]	{16}	11.50	[4.9]	0.96	<.39	{655}	12.49	[4.8]	{43}	13.32	[5.0]	{16}	12.01	[4.9]	0.78	<.46

* Significant effect across 3 groups

§ Mean adjusted for parental report of management difficulties and aggression, measures of maternal emotional responsiveness and punitiveness, stress, parental changes, family exposure to adverse life events 1-10 years, child's birth weight, maternal age, maternal education and socioeconomic status.

† Significantly different from reference group, Scheffé test.

∫ Significantly different from inpatient group, Scheffé test

^ Average score on Burt Word Reading Test over ages 8-13.

‡ Scores on reading comprehension at ages 10 & 12, derived from Progressive Achievement Test.

~ Scores on mathematics achievement at ages 11, derived from Progressive Achievement Test.

Unadjusted means for children who were injured prior to age five, the 0-5 year mild head injury group, are displayed on the left hand side of Table 12. These measures are provided in terms of mothers ratings, teacher ratings and a combined score. Looking first at the mean ratings of attention for each group (reference [no injury]; Outpatient; Inpatient) averaged over the 10-13 years of age, a head injury status main effect was evident for mother, $F\,(2, 869) = 4.15, p < 0.02$, MSE = 26.0 and combined ratings, $F\,(2, 848) = 3.44, p < 0.03$, MSE = 20.0. Teacher ratings of attention failed to reach significance, $F\,(2, 848) = 2.89, p < 0.06$, MSE = 26.9. Post-hoc Scheffé tests confirmed that mother, and combined ratings for the Inpatient group were higher than those of both the reference group ($p < 0.001$ $p < 0.004$) and outpatient group ($p < 0.020, p < 0.003$, respectively). For teachers ratings of attention the Inpatient group were higher than the reference group ($p < 0.01$).

Similar outcomes were apparent for mean ratings of conduct averaged over 10-13 years of age (left hand side of Table 12). A head injury status main effect was evident for mother, $F\,(2, 869) = 3.83, p < 0.02$, MSE = 90.4 teacher, $F\,(2, 848) = 5.29, p < 0.01$, MSE = 96.0, and combined ratings, $F\,(2, 848) = 6.06, p < 0.00$, MSE = 71.0. Post-hoc Scheffé tests confirmed that teacher and combined ratings for the Inpatient 0-5 group were higher than those of both the reference ($p < 0.006, p < 0.001, p < 0.001$) and outpatient group ($p < 0.003, p < 0.007$). For mother ratings of conduct the Inpatient group were higher than the reference group ($p < 0.001$).

Analyses of Unadjusted Means for Behavioural Outcomes Averaged Across Years 7-13

Unadjusted mean ratings of attention for each group (reference [no injury]; Outpatient; Inpatient averaged over 7-13 years of age are shown on the left hand side of Table 12. A head injury status main effect was evident for mother, $F\,(2, 869) = 4.45, p < 0.01$, MSE = 42.5 teacher, $F\,(2, 841) = 3.77, p < 0.02$, MSE = 41.4, and combined ratings of attention, $(2, 841) = 4.04, p < 0.02$, MSE = 32.30. Post-hoc Scheffé tests confirmed that mother ratings for the Inpatient 0-5 group were higher than those of both the reference group ($p < 0.001$) and the out patient group ($p < 0.011$). For teacher and combined ratings of attention the Inpatient group were higher than the reference group ($p < 0.007, p < 0.004$, respectively).

Unadjusted mean ratings of conduct averaged over 7-13 years of age are shown on the left hand side of Table 12. A head injury status main effect was evident for mother, $F\,(2, 869) = 4.49, p < 0.01$, MSE = 131.7, teacher, $F\,(2, 841) = 5.50, p < 0.01$, MSE = 130.4, and combined ratings, $F\,(2, 841) = 6.91, p < 0.00$, MSE = 99.5. Post-hoc Scheffé tests confirmed that combined ratings of conduct for the Inpatient 0-5 year group were higher than those of both the reference ($p < 0.001$) and outpatient groups ($p < 0.024$). For mother and teacher ratings of conduct, the Inpatient group were higher than the reference group (both $p < 0.002$).

Analyses of Unadjusted Means for Behavioural Outcomes Averaged Across years 7-9

Unadjusted mean ratings of attention averaged over the 7-9 year age period were also analysed for the 0-5 group and are shown on the left hand side of of Table 12. A head injury status main effect was evident for mother, F (2, 936) = 7.00, $p < 0.001$, MSE = 23.1, teacher, F (2, 926) = 4.21, $p < 0.02$, MSE = 22.3 and combined ratings, F (2, 926) = 6.01, $p < 0.001$, MSE = 16.9. Post-hoc Scheffé tests confirmed that mother, teacher and combined ratings for the Inpatient 0-5 group were higher than those of the reference group ($p < 0.002$, $p < 0.05$, $p < 0.04$, respectively).

A head injury status main effect was evident for unadjusted mean ratings of conduct, averaged over 7-9 years of age, on mother, F (2, 936) = 5.83, $p < 0.001$, MSE = 60.7, teacher, F (2, 926) = 4.0, $p < 0.02$, MSE = 60.5 and combined ratings of conduct, F (2, 926) = 6.70, $p < 0.01$, MSE = 42.7. Teacher ratings of conduct failed to reach significance. Post-hoc Scheffé tests confirmed that mother and combined ratings for the Inpatient 0-5 group were higher than those of the reference group ($p < 0.009$, $p < 0.013$, respectively).

Main Analyses of Adjusted Means for Behavioural outcomes 0-5 year group

Adjusted means for the 0-5 groups, are displayed on the right hand side of Table 12. For the main analyses mean ratings of attention for each group (reference[no injury]; Outpatient; Inpatient) was averaged over 10-13 years of age. A head injury status main effect was evident for mother, F (2, 860) = 5.43, $p < 0.01$, MSE = 22.9, teacher, F (2, 839) = 3.1, $p < 0.05$, MSE = 26.5, and combined ratings, F (2, 839) = 3.86, $p < 0.03$, MSE = 18.3. Post-hoc Scheffé tests confirmed mother, teacher and combined ratings for the inpatient 0-5 group were higher than those of both the reference ($p < 0.001$, $p < 0.005$, $p < 0.007$) and outpatient groups ($p < 0.001$, $p < 0.05$, $p < 0.001$ respectively); the latter two groups showed similar mean ratings.

Mean ratings of conduct averaged over 10-13 years are shown on the right hand side of Table 12. A head injury status main effect was evident for teacher, F (2, 839) = 6.2, $p < 0.002$ MSE, = 86.4 and combined ratings, F (2, 839) = 5.75, $p < 0.001$, MSE = 56.3. Mother ratings of conduct failed to reach significance. Post-hoc Scheffé tests confirmed that teacher and combined ratings for the inpatient group were higher than those of both the reference (all $p < 0.001$) and outpatient group ($p < 0.003$, $p < 0.002$); the latter two groups showed similar mean ratings.

Analyses of Adjusted Means for Behavioural Outcomes Averaged Across Years 7-13

Mean ratings of attention for each group averaged over 7-13 years of age are shown on the right hand side of Table 12. A head injury status main effect was evident for mother, F (2, 860) = 4.27, $p < 0.02$, MSE = 35.1 teacher, F (2, 832) = 3.04, $p < 0.05$, MSE = 40.6 combined ratings, F (2, 832) = 3.00, $p < 0.05$, MSE = 28.2. Post-hoc Scheffé tests confirmed that mother, and combined ratings of attention for the Inpatient 0-5 group were higher than those of both the reference group (both $p < 0.001$) and the outpatient group ($p < 0.003$, $p < 0.03$). For teacher ratings of attention the Inpatient group were higher than the reference group ($p < 0.003$).

Mean ratings of conduct averaged over 7-13 of age are shown on the right hand side of Table 12. Teacher, F (2, 832) = 4.65, $p < 0.01$, MSE = 115.9, and combined ratings of conduct F (2, 832) = 5.00, $p < 0.01$, MSE = 75.0. Mother ratings of conduct just failed to reach significance, F (2, 860) = 2.93, $p < 0.06$, MSE = 93.8, Post-hoc Scheffé tests confirmed that mother, teacher and combined ratings of conduct for the Inpatient 0-5 group were higher than those of both the reference group (all $p < 0.001$) and the outpatient group ($p < 0.015$, $p < 0.003$, $p < 0.005$); the latter two groups showed similar mean ratings.

Analyses of Adjusted Means for Behavioural Outcomes Averaged Across Years 7-9

Adjusted mean ratings of attention averaged over 7-9 years of age are shown on the right hand side of Table 12. When analyses were restricted to 7-9 years a head injury status main effect was evident for only mothers ratings of attention, F (2, 927) = 3.1, $p < 0.05$, MSE = 18.8. Teacher and combined ratings of attention, and mother, teacher and combined ratings of conduct, failed to reach significance. Post-hoc Scheffé tests confirmed that mother ratings of attention for the Inpatient 0-5 group were higher when compared to those of the reference group ($p < 0.001$).

Analyses of Unadjusted/Adjusted Means of Cognitive outcomes for 0-5 year group.

As is shown at the bottom of Table 12, for both unadjusted and adjusted means, none the outcome measures used to detect cognitive or academic differences were significant.

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Table 13. Head injury outcome effect size, 0-5 years of age at injury

	Unadjusted Means				Adjusted Means			
	Effect Size				Effect Size			
	Cohen's d	95% CI (d) ∫	r	BESD †	Cohen's d	95% CI (d) ∫	r	BESD †
Attention ratings outcome averaged over years 10-13								
Mothers	0.905	0.422 – 1.387	0.413	29.4% – 70.7%	0.618	0.137 – 1.010	0.296	35.2% – 64.8%
Teachers	0.789	0.292 – 1.285	0.367	31.7% – 68.4%	0.582	0.087 – 1.078	0.280	36.0% – 64.0%
Combined	0.864	0.367 – 1.360	0.397	30.2% – 69.9%	0.583	0.087 – 1.079	0.280	36.0% – 64.0%
Conduct ratings outcome averaged over years 10-13								
Mothers	0.797	0.315 – 1.278	0.370	31.5% – 68.5%	0.387	0.094 – 0.867	0.190	40.5% – 59.5%
Teachers	0.995	0.498 – 1.492	0.446	27.7% – 72.3%	0.815	0.319 – 1.312	0.378	31.1% – 68.9%
Combined	1.034	0.537 – 1.532	0.460	27.0% – 73.0%	0.727	0.231 – 1.224	0.342	32.9% – 67.1%
Attention ratings outcome averaged over years 7-13								
Mothers	0.931	0.448 – 1.413	0.472	26.4% – 73.6%	0.609	0.127 – 1.090	0.291	35.5% – 64.6%
Teachers	0.796	0.423 – 1.293	0.370	31.5% – 68.5%	0.578	0.082 – 1.074	0.279	36.1% – 64.0%
Combined	0.872	0.375 – 1.369	0.400	30.0% – 70.0%	0.515	0.019 – 1.011	0.250	37.5% – 62.5%
Conduct ratings outcome averaged over years 7-13								
Mothers	0.865	0.383 – 1.347	0.397	30.2% – 69.9%	0.482	0.001 – 0.963	0.235	38.3% – 61.7%
Teachers	0.922	0.425 – 1.419	0.419	29.1% – 71.0%	0.725	0.228 – 1.221	0.341	33.0% – 67.1%
Combined	1.016	0.518 – 1.513	0.453	27.4% – 72.7%	0.680	0.184 – 1.176	0.322	33.9% – 66.1%

Table 13. (continued) Head injury outcome effect size, 0-5 years of age at injury

	Unadjusted Means				Adjusted Means			
	Effect Size				Effect Size			
	Cohen's d	95% CI (d) ∫	r	BESD †	Cohen's d	95% CI (d) ∫	r	BESD †
Attention ratings outcome averaged over years 7-9								
Mothers	0.824	0.379 – 1.269	0.381	31.0% – 69.1%	0.502	0.058 – 0.946	0.244	37.8% – 62.2%
Teachers	0.589	0.134 – 1.045	0.283	35.9% – 64.1%	0.391	-0.064 – 0.846	0.192	40.4% – 59.6%
Combined	0.688	0.232 – 1.144	0.325	33.8% – 66.3%	0.394	-0.061 – 0.849	0.193	40.3% – 59.7%
Conduct ratings outcome averaged over years 7-9								
Mothers	0.693	0.248 – 1.137	0.327	33.7% – 66.4%	0.318	-0.126 – 0.761	0.157	42.2% – 57.9%
Teachers	0.474	0.019 – 0.929	0.231	38.5% – 61.6%	0.296	-0.159 – 0.950	0.146	42.7% – 57.3%
Combined	0.690	0.234 – 1.145	0.326	33.7% – 66.3%	0.367	-0.088 – 0.822	0.181	40.9% – 59.1%
Cognitive and academic outcomes								
IQ age 8	0.469	-0.013 – 0.950	0.228	38.6% – 61.4%	0.293	-0.188 – 0.774	0.145	42.8% – 57.3%
Burt	0.188	-0.343 – 0.718	0.094	45.3% – 54.7%	0.028	-0.502 – 0.558	0.014	49.3% – 50.7%
SchoolCert	0.531	0.035 – 1.026	0.257	37.2% – 62.9%	0.354	-0.141 – 0.849	0.174	41.3% – 58.7%
PAT10 ‡	0.231	-0.245 – 0.727	0.115	44.3% – 55.8%	0.125	-0.370 – 0.621	0.063	46.9% – 53.2%
PAT11 ~	0.310	-0.186 – 0.606	0.154	42.3% – 57.7%	0.295	-0.201 – 0.791	0.146	42.7% – 57.3%
PAT12 ‡	0.306	-0.190 – 0.802	0.151	42.4% – 57.6%	0.100	-0.396 – 0.596	0.050	47.5% – 52.5%

‡ Scores on reading comprehension at ages 10 & 12, derived from Progressive Achievement Test.

~ Scores on mathematics achievement at ages 11, derived from Progressive Achievement Test.

∫ Confidence Interval

† Binomial Effect Size Display

Effect sizes for Behavioural and Cognitive Outcomes

Effect sizes for behavioural and cognitive outcomes, both adjusted and unadjusted are shown on Table 13 and will be commented on in the discussion.

Analyses of Psychiatric outcomes for 0-5 year group.

Overall group differences for the 0-5 year group were significant for CD/ODD, (df (2) chi square = 9.64) and for substance abuse, (df (2) chi square = 8.38). There were no significant group differences for ADHD, (df (2) chi square = 4.91) mood disorders, (df (2) chi square = 1.20), anxiety disorders, (df (2) chi square = 1.09) or alcohol abuse/dependence, (df (2) chi square = 2.35).

Unadjusted Odds Ratios are shown on the left hand side of Table 9. The unadjusted Odds Ratio (OR) for ADHD (Inpat, OR = 5.61, $p < 0.01$, Outpat, OR = 2.35, $p < 0.08$), CD/ODD (Inpat, OR = 6.54, $p < 0.001$, Outpat, OR = 0.71, $p < 0.58$) and substance abuse/dependence (Inpat, OR = 9.36, $p < 0.001$, Outpat, OR = 1.19, $p < 0.81$) showed that children in 0-5 year inpatient group but not the outpatient group have a higher likelihood of developing these disorders when compared with the reference group. There were no significant differences for mood or anxiety disorders or alcohol abuse/dependence when analysed in terms of either inpatient or outpatient grouping.

Adjusted Odds Ratios are shown on the right hand side of Table 9. Initial findings remain when the covariates were added, inpatient groups had a higher likelihood of developing ADHD, (Inpat, OR = 4.63, $p < 0.03$, Outpat, OR = 1.71, $p < 0.34$) CD/ODD, (Inpat, OR = 5.58, $p < 0.01$, Outpat, OR = 0.51, $p < 0.29$) and substance abuse/dependence (Inpat, OR = 9.09, $p < 0.02$, Outpat, OR = 1.10, $p < 0.93$). There were no significant differences for mood or anxiety disorders or alcohol abuse/dependence when analysed in terms of either inpatient or outpatient grouping.

3.2.4 Group by year interactions For Repeated Measures for Attention, Conduct and Burt scores

These interactions were reported for adjusted means analyses of simple main effects. Where a significant group x year interaction was present, the simple main effects were analysed to evaluate changes of each individual group over the repeated measure(years) and differences between groups at each year. Adjusted means for the 0-10 injury group (reference [no injury] Outpatient; Inpatient) on mother, teacher and combined ratings of attention and conduct are shown on Figures 2-7. A simple main effect for time was evident on mother ratings of attention (Figure 2) for the reference, F (3, 2736) = 12.98 $p < 0.001$, MSE = 3.04; outpatient, F (3, 2736) = 3.61, $p < 0.01$, MSE = 3.04; and inpatient groups, F (3, 2736) = 4.28, $p < 0.005$, MSE = 3.04. There was also a simple main effect for years with significant differences between the groups on years 11, F (2, 900) = 6.99, $p < 0.001$, MSE = 8.34, 12, F (2, 900) = 5.14 $p < 0.007$, MSE = 8.99, and 13, F (2, 900) = 4.03 $p < 0.019$, MSE = 6.82 but not year 10 F (2, 900) = 0.46 $p < 0.064$, MSE = 7.89. There were no significant group x year interactions for teacher (Figure 3) or combined ratings of attention (Figure 4). No other measures produced a group x year interaction in the 0-10 group (Figures 5-7)

Group by Year Interactions Adjusted 6-10

Adjusted means for the 6-10 injury group (reference [no injury] Outpatient; Inpatient) on mother, teacher and combined ratings of attention and conduct are shown on Figures 8-13. There were no group by year interaction for any measures in the 6-10 year groups

Group by Year Interactions Adjusted 0-5

Adjusted means for the 0-5 injury group (reference [no injury] Outpatient; Inpatient) on mother, teacher and combined ratings of attention and conduct are shown on Figures 14-19. When means were adjusted a head injury status (group) x year interaction was evident for mothers ratings of attention, over 7-9, 10-13, and 7-13 years. As the 7-13 year analyses covers all time frames, these will be presented here. In this instance, there was a highly significant interaction F (12, 5232) = 3.65 $p < 0.001$, MSE = 3.74. Mother ratings of attention are shown in Figure 14. A simple main effect for time was evident on mother ratings of attention for the reference, F (6, 5232) = 24.31 $p < 0.001$, MSE = 3.74; outpatient, F (6, 5232) = 8.79, $p < 0.001$, MSE = 3.04; and inpatient groups, F (6, 5232) = 4.74, $p < 0.001$, MSE = 3.74. There was also simple main effect for years, 7 F (2, 860) = 3.68 $p < 0.03$; 11, F (2, 860) = 9.23 $p < 0.001$, MSE = 8.31, 12, F (2, 860) = 6.62, $p < 0.007$, MSE = 8.91; and 13, F (2, 802) = 3.36 $p < 0.035$, MSE = 6.79 but not for years 8 F (2, 860) = 1.99, $p < 0.14$, MSE = 9.91; 9 F (2, 860) = 1.36, $p < 0.26$, MSE = 7.06; and 10 F (2, 860) = 0.33 $p < 0.72$, MSE = 7.79.

text continues on page 98

Table 12. (continued) Head injury status 0-5 years of age at injury

	Unadjusted Means					Adjusted Means §				
	Reference	Outpatient	Inpatient			Reference	Outpatient	Inpatient		
	{n=} Mean [SD]	{n=} Mean [SD]	{n=} Mean [SD]	F	p-level	{n=} Mean [SD]	{n=} Mean [SD]	{n=} Mean [SD]	F	p-level
Attention and Conduct ratings outcome averaged over years 7-9 (continued)										
Conduct										
Mothers	{867} 28.02 [4.5]	{55} 29.25 [4.8]	{20} 31.18 [6.7]†	5.83	<.00*	{867} 28.98 [4.5]	{55} 29.04 [4.8]	{20} 30.43 [6.7]	1.43	<.24
Teachers	{858} 22.97 [4.5]	{55} 24.35 [6.2]	{19} 25.12 [5.8]	4.00	<.20	{858} 23.52 [4.5]	{55} 24.06 [6.2]	{19} 24.86 [5.8]	1.25	<.29
Combined	{858} 25.50 [3.8]	{55} 26.80 [4.7]	{19} 28.15 [5.4]†	6.70	<.00*	{858} 26.24 [3.8]	{55} 26.55 [4.7]	{19} 27.65 [5.4]	1.89	<.16
Cognitive and academic outcomes										
IQ age 8	{712} 102.3 [15.2]	{48} 101.2 [15.2]	{17} 95.10 [19.5]	1.60	<.21	{712} 100.9 [15.2]	{48} 101.4 17.0]	{17} 96.4 [19.5]	0.86	<.43
BURT ^	{569} 67.23 [17.9]	{41} 67.20 [17.9]	{14} 63.87 [16.6]	0.09	<.91	{569} 65.94 [17.9]	{41} 66.92 [19.8]	{14} 65.44 [16.6]	0.07	<.94
SchoolCert	{787} 3.36 [2.2]	{51} 3.47 [2.2]	{16} 2.19 [2.3]	2.56	<.08	{787} 3.14 [2.2]	{51} 3.51 [2.4]	{16} 2.36 [2.3]	2.17	<.12
PAT10 ‡	{695} 10.48 [7.0]	{47} 10.19 [7.0]	{16} 8.86 [7.4]	0.38	<.69	{695} 9.93 [7.0]	{47} 10.26 [7.8]	{16} 9.05 [7.4]	0.20	<.82
PAT11 ~	{679} 25.14 [7.3]	{44} 25.57 [7.3]	{16} 22.87 [7.5]	1.37	<.26	{679} 24.64 [7.3]	{44} 25.46 [8.6]	{16} 22.48 [7.5]	1.09	<.34
PAT12 ‡	{655} 12.97 [4.8]	{43} 13.35 [4.8]	{16} 11.50 [4.9]	0.96	<.39	{655} 12.49 [4.8]	{43} 13.32 [5.0]	{16} 12.01 [4.9]	0.78	<.46

* Significant effect across 3 groups

§ Mean adjusted for parental report of management difficulties and aggression, measures of maternal emotional responsiveness and punitiveness, stress, parental changes, family exposure to adverse life events 1-10 years, child's birth weight, maternal age, maternal education and socioeconomic status.

† Significantly different from reference group, Scheffé test.

∫ Significantly different from inpatient group, Scheffé test

^ Average score on Burt Word Reading Test over ages 8-13.

‡ Scores on reading comprehension at ages 10 & 12, derived from Progressive Achievement Test.

~ Scores on mathematics achievement at ages 11, derived from Progressive Achievement Test.

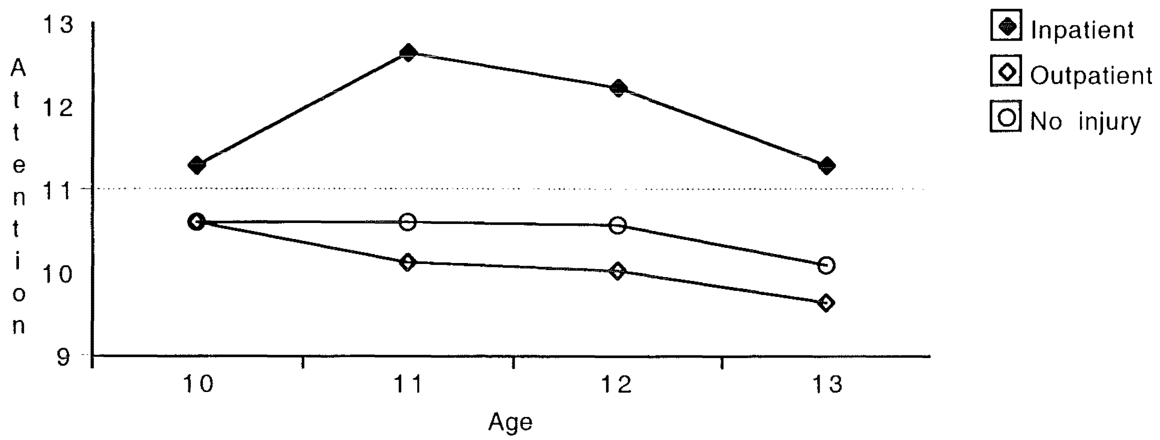

Figure 2. Mothers rating of attention, 0-10 years grouping, adjusted means

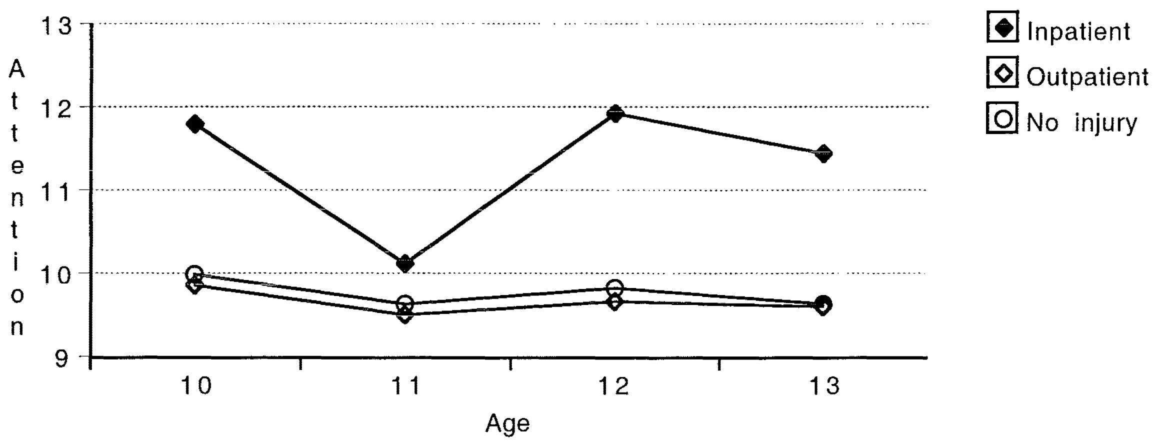

Figure 3. Teachers rating of attention, 0-10 years grouping, adjusted means

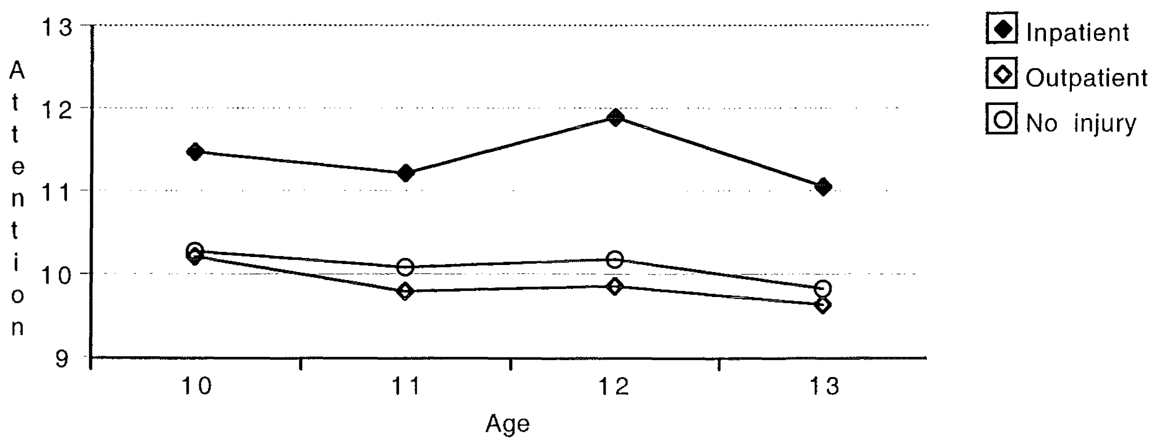

Figure 4. Combined mothers & teachers rating of attention, 0-10 years grouping, adjusted mean

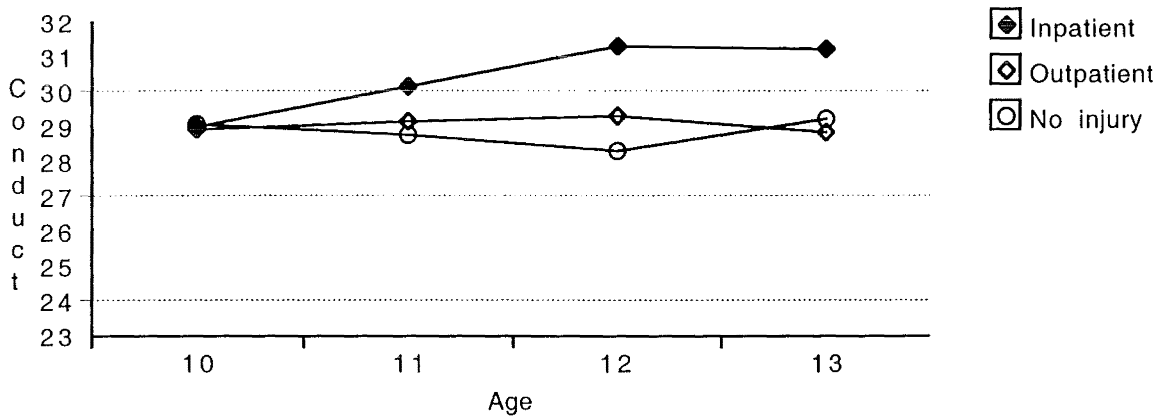

Figure 5. Mothers rating of conduct, 0-10 years grouping,, adjusted means

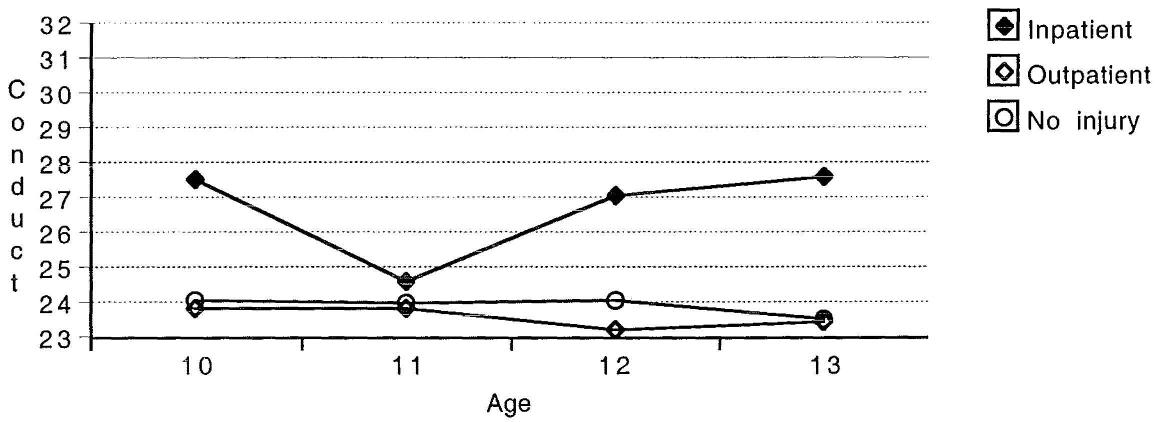

Figure 6. Teachers rating of conduct, 0-10 years grouping, adjusted means

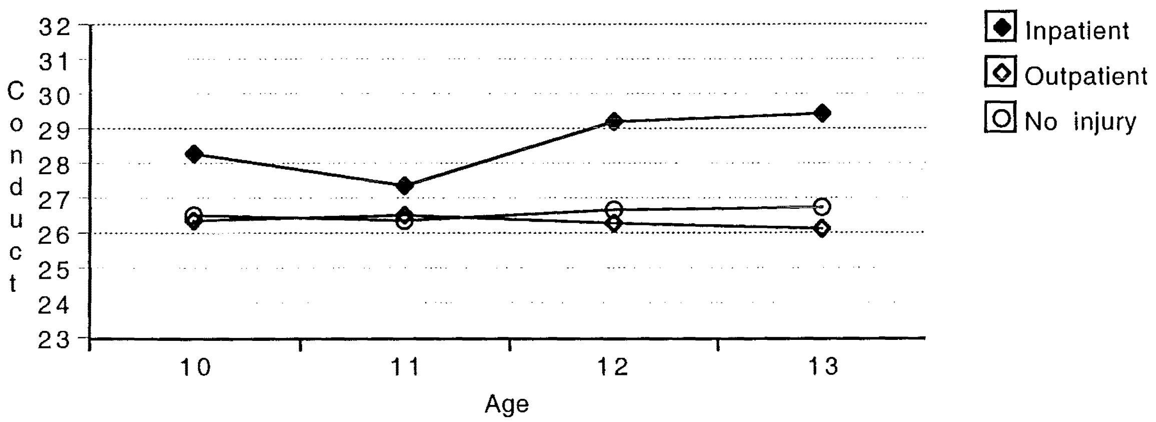

Figure 7. Combined mothers & teachers rating of conduct, 0-10 years grouping, adjusted means

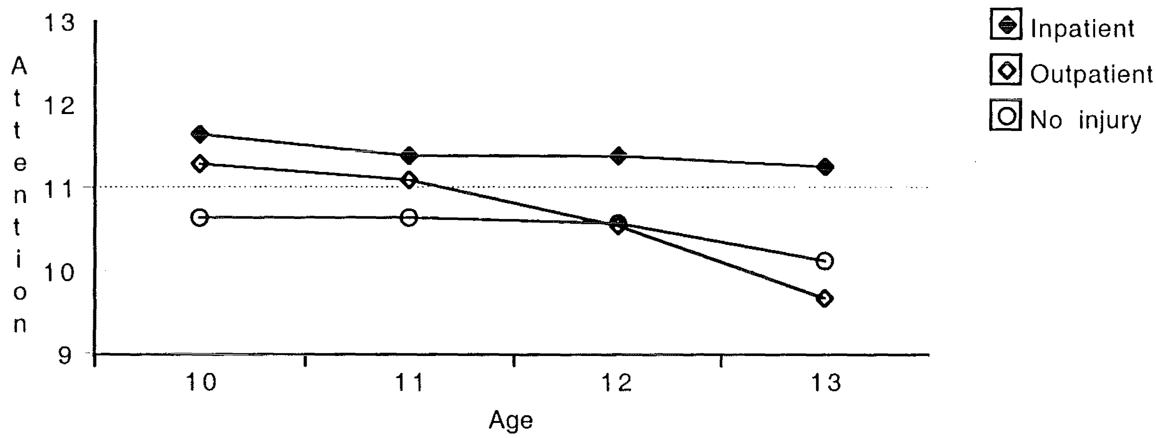

Figure 8. Mothers rating of attention, 6-10 years grouping, adjusted means

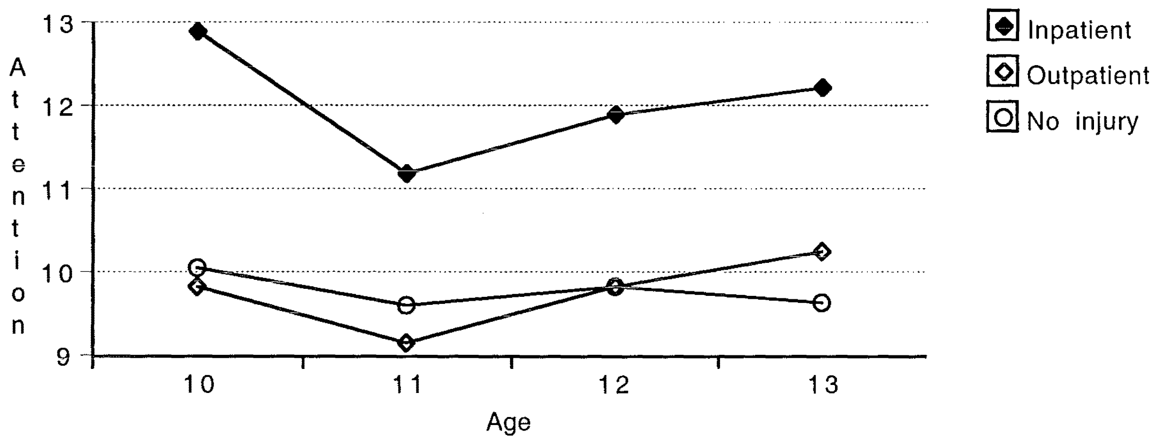

Figure 9. Teachers rating of attention, 6-10 years grouping, adjusted means

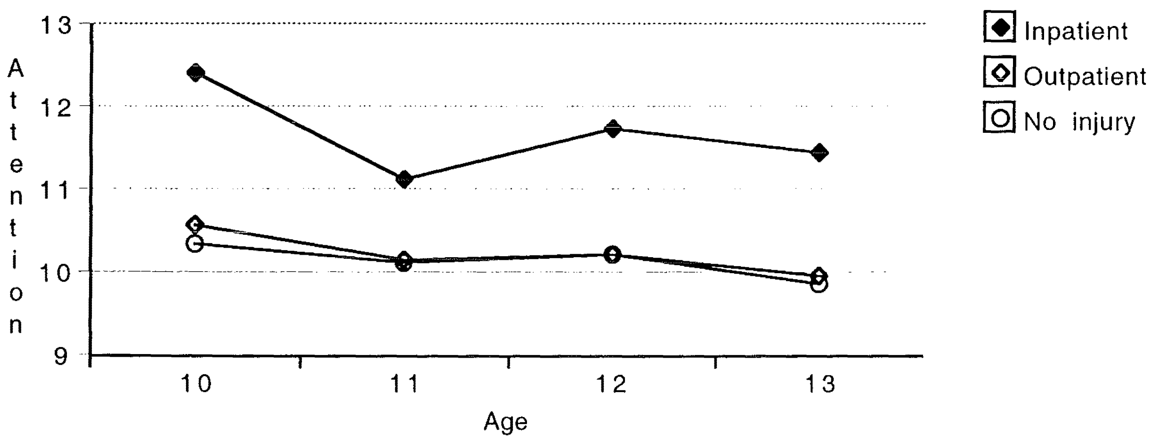

Figure 10. Combined mothers & teachers rating of attention, 6-10 years grouping, adjusted mea

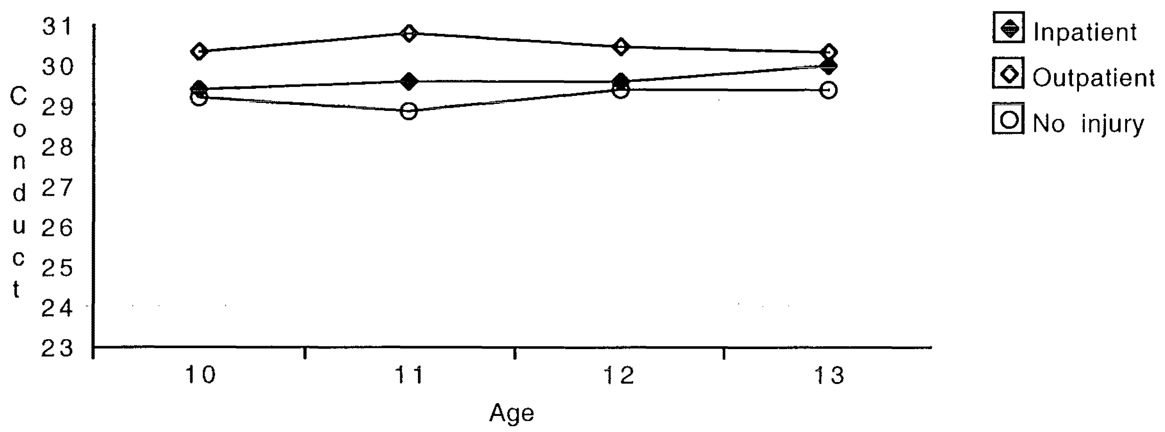

Figure 11. Mothers rating of conduct, 6-10 years grouping, adjusted means

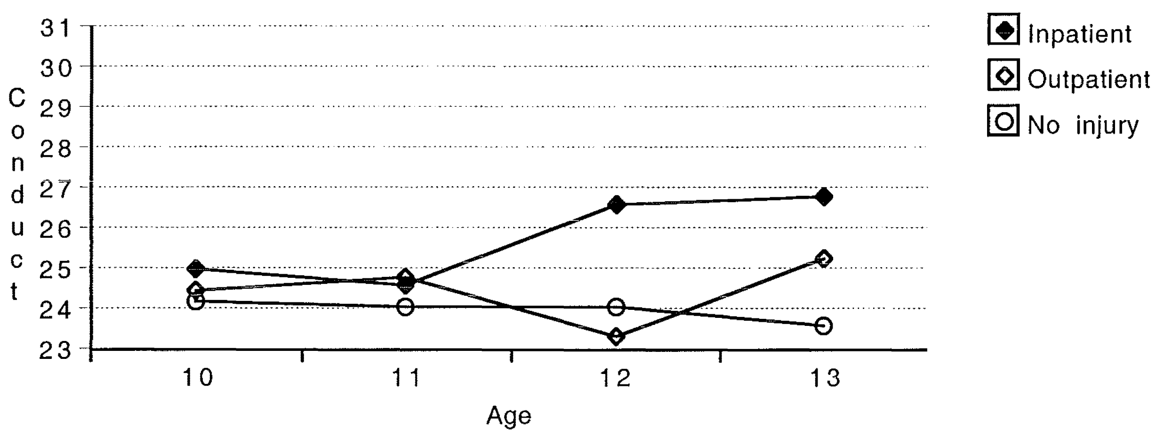

Figure 12. Teachers rating of conduct, 6-10 years grouping, adjusted means

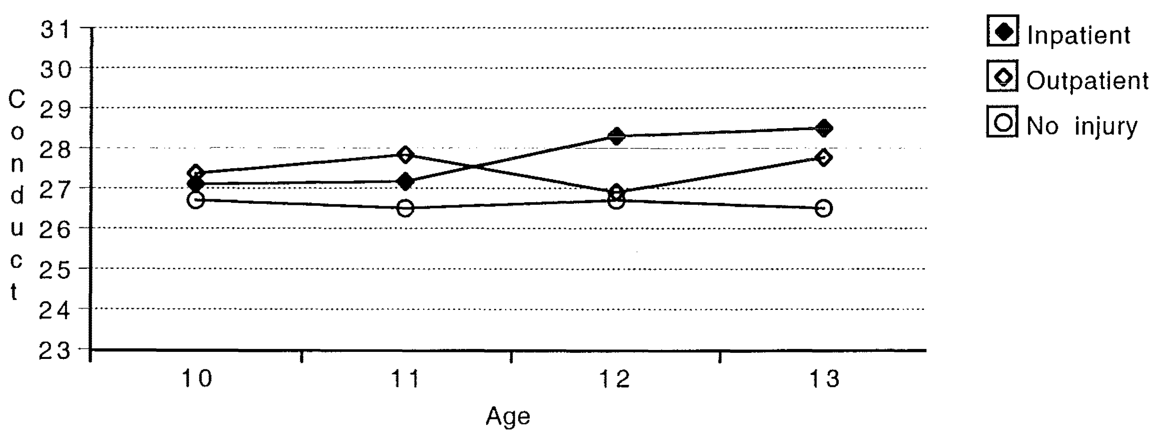

Figure 13. Combined mothers & teachers rating of conduct, 6-10 years grouping, adjusted mear

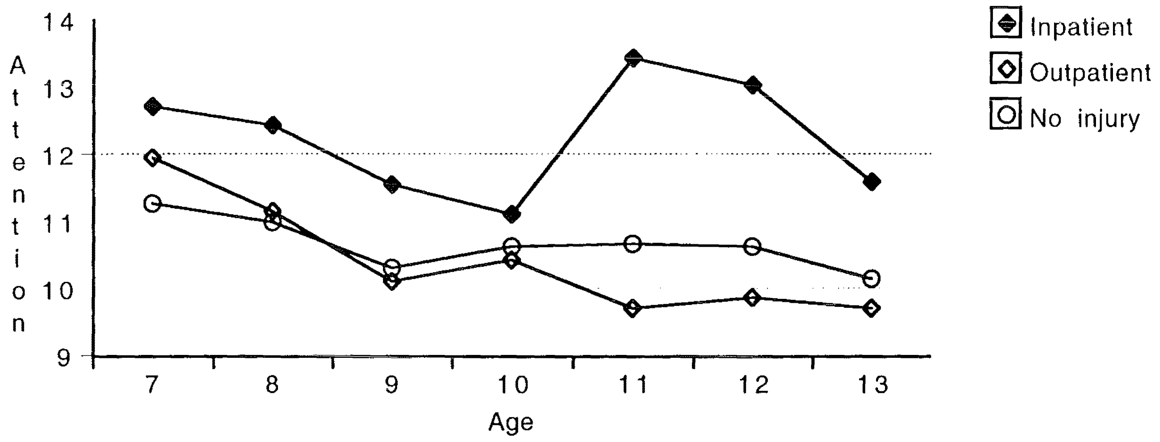

Figure 14. Mothers rating of attention, 0-5 years grouping, adjusted means

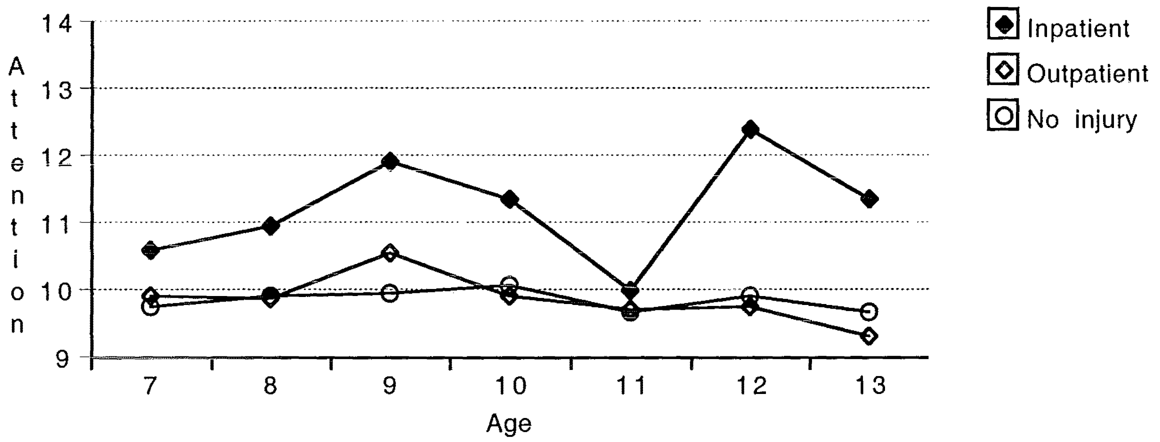

Figure 15. Teachers rating of attention, 0-5 years grouping, adjusted means

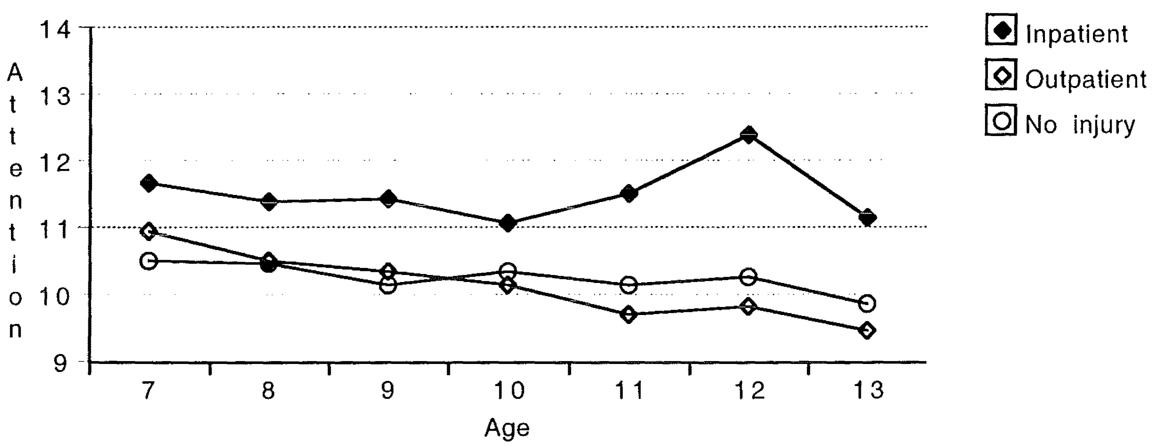

Figure 16. Combined mothers & teachers rating of attention, 0-5 years grouping, adjusted mean

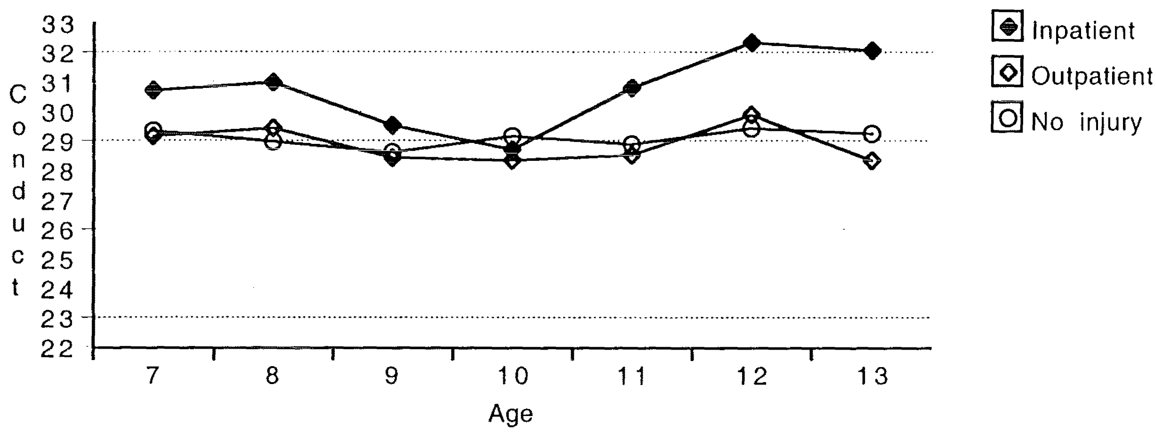

Figure 17. Mothers rating of conduct, 0-5 years grouping, adjusted means

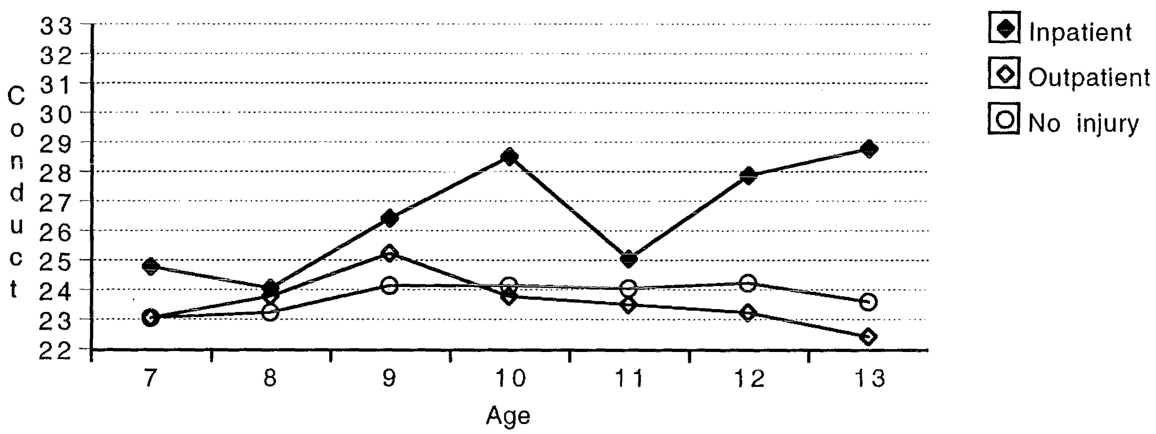

Figure 18. Teachers rating of conduct, 0-5 years grouping, adjusted means

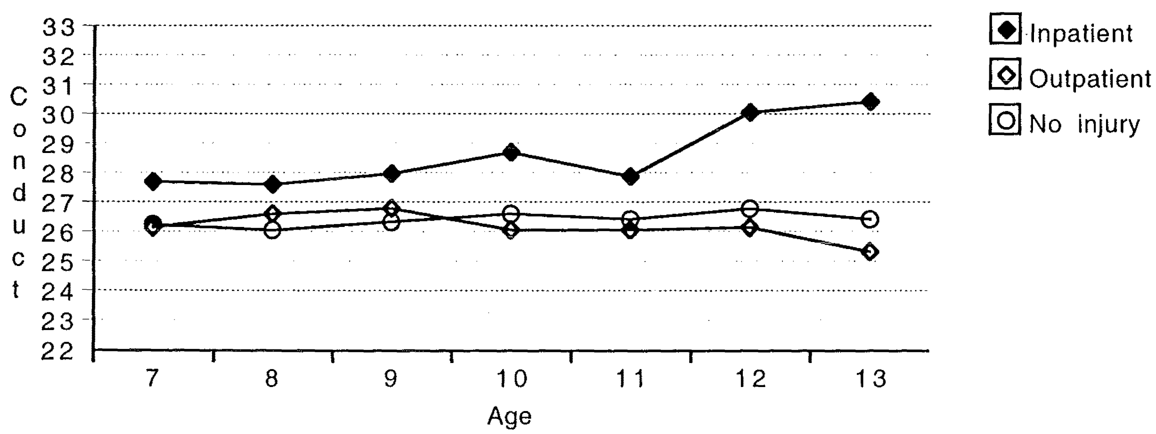

Figure 19. Combined mothers & teachers rating of conduct, 0-5 years grouping, adjusted means

When means were adjusted a Head injury status (group) x year interaction was evident for teacher ratings of attention over the period 10-13 years, F (6, 2553) = 2.15 $p < 0.045$, MSE = 4.64. Teacher ratings of attention are shown in Figure 15. A simple main effect for time was evident on teacher ratings of attention for the reference, F (2, 2553) = 3.95 $p < 0.009$, MSE = 4.64, and inpatient groups, F (2, 2553) = 3.97, $p < 0.008$, MSE = 4.64, but not for the outpatient group, F (2, 2553) = 0.70, $p < 0.550$, MSE = 4.64; There was a simple main effect for years, 12 F (2, 839) = 5.81 $p < 0.004$, MSE = 10.74 and 13, F (2, 839) = 2.68 $p < 0.070$, MSE = 9.24, but not year 10, F (2, 839) = 1.61, $p < 0.21$, MSE = 10.87, and 11, F (2, 839) = 0.29, $p < 0.75$, MSE = 9.48.

A head injury(status group) x year interaction was evident over years 7-13 for combined mother and teacher ratings of attention(shown in Figure 16), F (12, 5064) = 2.31 $p < 0.0062$, MSE = 2.42. A simple main effect for time was evident for the reference, F (6, 5064) = 9.75 $p < 0.001$, MSE = 2.24, outpatient, F (6, 5064) = 4.82, $p < 0.001$, MSE = 2.42; but not inpatient groups, F (6, 5064) = 1.93, $p < 0.073$, MSE = 2.42. There were also significant differences between the groups on years, 12 F (2, 832) = 6.54 $p < 0.002$, MSE = 6.66 and 13, F (2, 832) = 3.01 $p < 0.050$, MSE = 5.42 but not year 7, F (2, 832) = 1.78, $p < 0.17$, MSE = 6.17; 8, F (2, 832) = 1.85, $p < 0.16$, MSE = 6.94; 10, F (2, 832) = 0.79, $p < 0.46$, MSE = 6.25 or 11 F (2, 832) = 2.77, $p < 0.64$, MSE = 6.25.

A head injury(status group) x year interaction was evident over years 10-13 teacher ratings of conduct(shown in Figure 12)F (6, 2553) = 2.14 $p < 0.047$, MSE = 16.24. A simple main effect for time was evident on teacher ratings of conduct over 10-13 years for the inpatient group, F (3, 2553) = 2.66, $p < 0.047$, MSE = 16.24, but not the outpatient group, F (3, 2553) = 1.85, $p < 0.14$, MSE = 16.24 or the reference group, F (3, 2553) = 1.64, $p < 0.18$, MSE = 16.24. There was a simple main effect for years, 10 F (2, 839) = 6.22, $p < 0.03$; MSE 33.64, 12, F (2, 839) = 3.95, $p < 0.020$, MSE 34.21, and 13, F (2, 839) = 8.20, $p < 0.001$, MSE = 28.83, but not year 11, F (2, 839) = 0.73, $p < 0.49$, MSE = 34.27. There were no head injury(status group) x year interactions mother ratings of conduct(shown in Figure 17).

A Head injury status (group) x year interaction, shown in Figure 19, was evident over the period of years 7-13 for combined mother and teacher ratings of conduct, F (12, 5064) = 2.22, $p < 0.009$ = MSE 6.88. A simple main effect for years was evident for the reference, F (6, 5064) = 8.35, $p < 0.001$, MSE = 6.88, and inpatient group, F (6, 5064) = 2.95 $p < 0.007$, MSE = 6.88, but not outpatient group, F (6, 5064) = 1.34, $p < 0.24$, MSE = 6.88. There was a simple main effect for group on years, 8 $F(2, 832) = 3.19$ $p < 0.042$, MSE = 12.43, 9 $F(2, 832) = 3.17$ $p < 0.042$, MSE = 15.00, 10 $F(2, 832) = 4.08$ $p < 0.017$, MSE = 17.73, 12 $F(2, 832) = 4.50$ $p < 0.011$, MSE = 21.87 and 13, $F(2, 832) = 8.97$, $p < 0.001$, MSE = 16.67, but not year 7, $F(2, 832) = 1.65$, $p <$ 1.93, MSE = 13.08, or 11 $F(2, 832) = 1.47$, $p < 0.23$, MSE = 19.16.

3.3.1 Further analysis of attention and conduct

The main analysis of this study focused on the association between head injury and a number of behavioural and cognitive outcomes after controlling for potential confounding variables. Results suggest that behavioural outcomes are strongly related to mild head injury. This relationship was especially strong for children who had received inpatient care. Therefore, in addition to the main covariate analysis, a descriptive analysis was conducted to examine the effects of head injury on behaviour from a different perspective. It has been suggest in previous research that children who experience head injury differ from other children in terms of their pre-injury behaviour, and any deficits post-injury would be strongly related to this. The purpose of the additional analysis here was that if mild head injury does not contribute to post-injury behaviour, it would be expected that children in the head injury group would be similar to children in the reference group who initially had identical scores of attention and conduct at age 7, the earliest year when the Conners/Rutter ratings were taken. Thus to further explore the possible relationship between attention, conduct and head injury, each child in the inpatient 0-10 year mild head injury group and the 0-5 year subgroup was matched with 3 other children from the reference group (for whom there were no missing data) randomly selected from all those reference children who had that exact score for attention and conduct at age 7. This matching was done for each of mother ratings of attention, teacher ratings of attention, mothers ratings of conduct and teacher ratings of conduct. In this way, each of the 36 inpatient children in the 0-10 year group were matched for attention and conduct ratings respectively, giving four sets of 108 non-injured children randomly selected from the reference group children who had been give comparable ratings at age 7. There were 21 children in the inpatient 0-5 year subgroup matched with four sets of 63 children, as before these were randomly selected from the reference group children who had been give comparable ratings at age 7. All children in each of the groups were identical in terms of scores on mother and teacher ratings of attention and conduct at age seven. In this way it was possible to investigate changes in the behaviour of the children over time. Note, again, that this analysis is conservative in that it biases against finding injury effects because it artificially increases the reference group mean at age seven.

3.3.2 Descriptive analysis for attention and conduct in 0-10 year group

The inpatient head injury group and the matched non-injured children from the reference group were split into upper and lower groups by means of a median split to examine changes in behaviour of the children in terms of high or low scores. The scores of the children over years 7-13 for combined mother and teacher ratings of attention for the 0-10 year group are shown in Figure 22. Children who were initially rated as having high attention scores, in both the injury and non injury groups, have scores that are similar across the years with a general downward trend being apparent. However, a different pattern emerges for children who were initially rated as having low scores on measures of attention. Scores for children in the mild injury group increase over the years in comparison to the children in the reference group. As can be seen in Figures 20 and 21, similar trends are apparent for both mother and teacher ratings of attention.

Combined mother and teacher ratings of conduct are shown in Figure 25. As with the analysis of attention, both the inpatient head injury group and the matched non-injured children from the reference group were split into upper and lower groups by means of a median split on their scores of conduct. For combined mother and teacher ratings of conduct, children in the head injury group, regardless of whether their initial scores were high or low, show generally increasing trend for problems with conduct. A similar pattern was evident for teacher ratings of conduct (Figures 24). For mother ratings of conduct, both the upper and lower groups had similar scores for the seven years over which scores are analysed (Figure 23).

3.3.3 Descriptive analysis for attention and conduct in 0-5 year subgroup

Although the groups were matched on scores of attention and conduct, a number of the children in the 0-10 group experienced their head injury during the period that scores were collected. The 0-5 subgroup provides a group of children all of whom had their injury at least two years prior to scores of attention or conduct being taken. Also, deficits may be more evident as the child matures and greater demands are placed on the child in terms of expected behaviour. As a result of both of these issues it may be expected that if increased behaviour problems are related to mild head injury, a greater difference between the head injury and reference group scores would be apparent for this group.

Mother and teacher ratings of attention for the 0-5 year inpatient head injury group and matched children from the reference groups, split into upper and lower groups by means of a

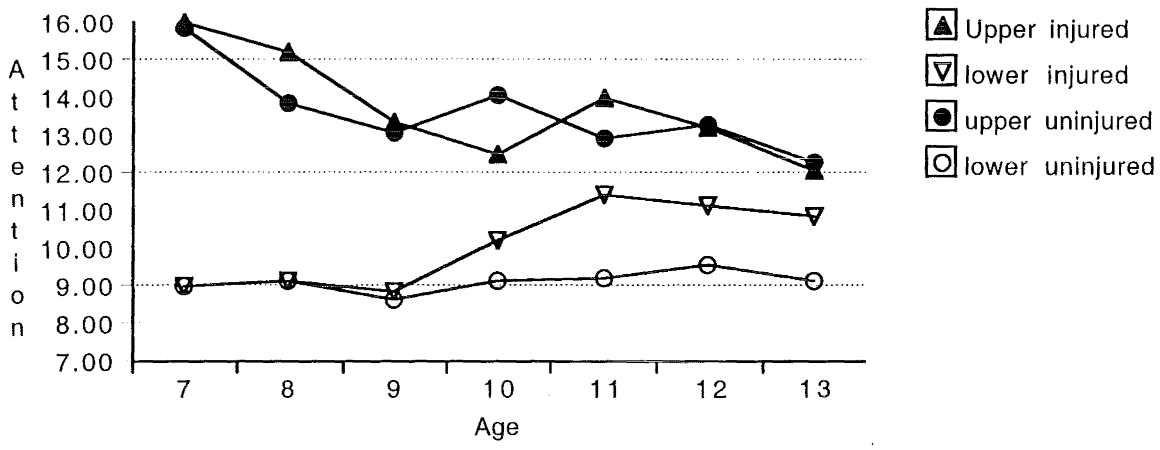

Figure 20. Mothers ratings of attention, non injury subgroup matched to 0-10 injury group: Median split

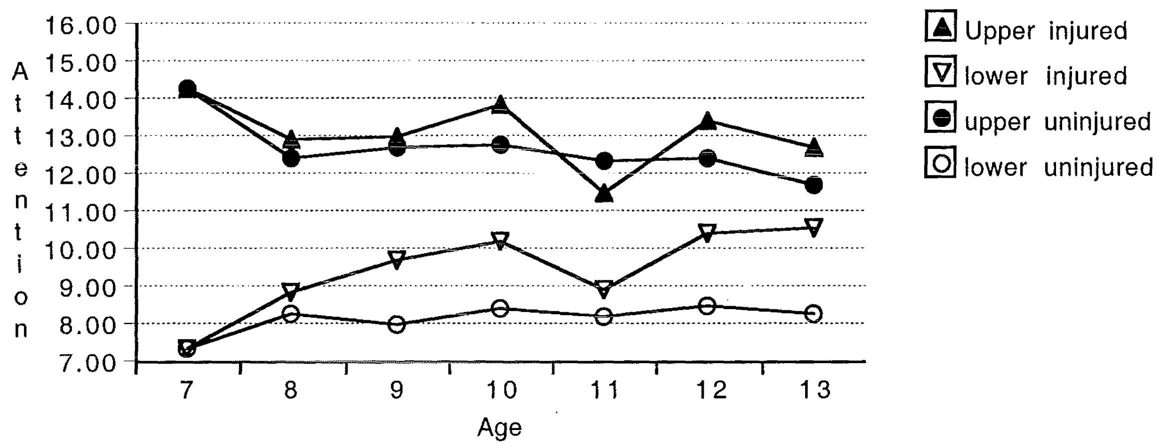

Figure 21. Teachers ratings of attention, non injury subgroup matched to 0-10 injury group: Median split

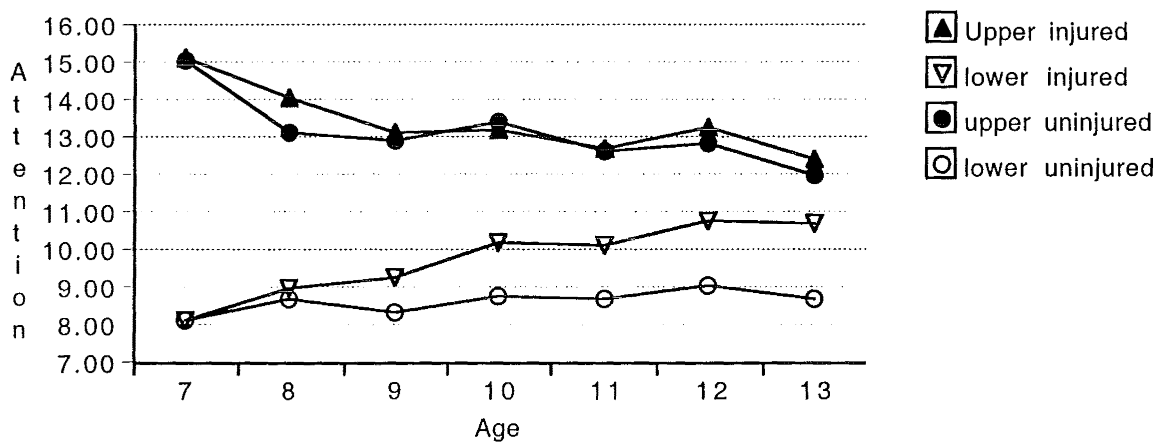

Figure 22. Combined Mother/Teacher attention ratings, 0-10 injury/non injury subgroups matched: Median split

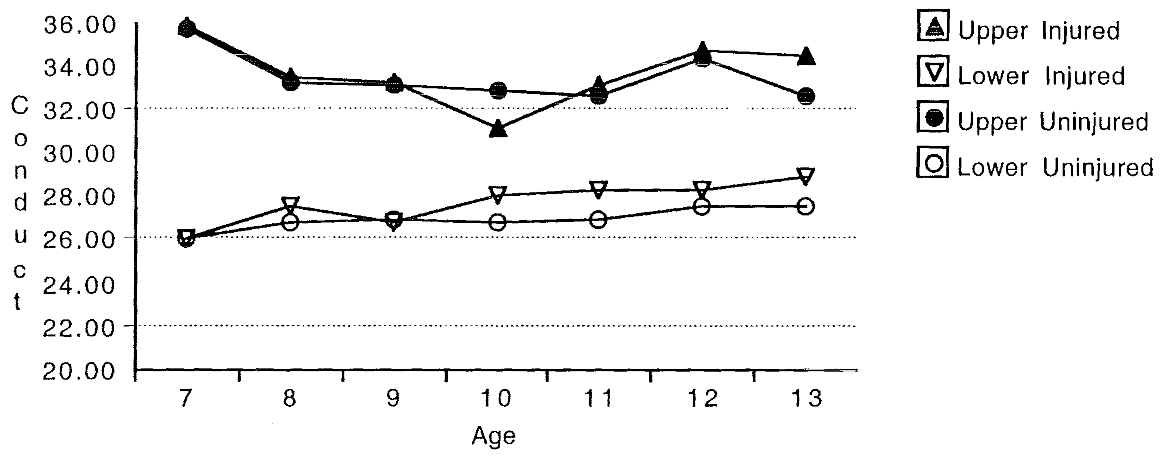

Figure 23. Mothers ratings of conduct non injury subgroup matched to 0-10 injury group: Median split

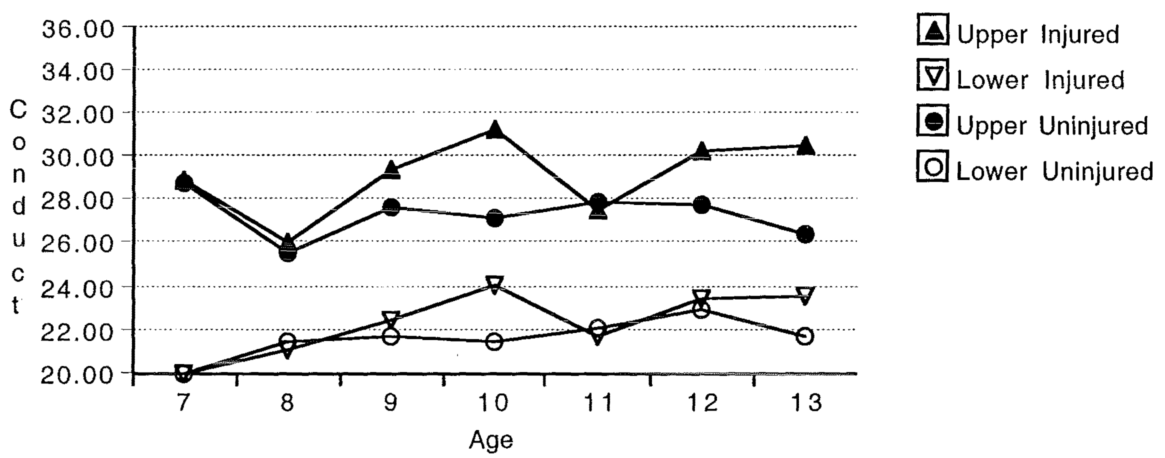

Figure 24. Teachers ratings of conduct non injury subgroup matched to 0-10 injury group: Median split

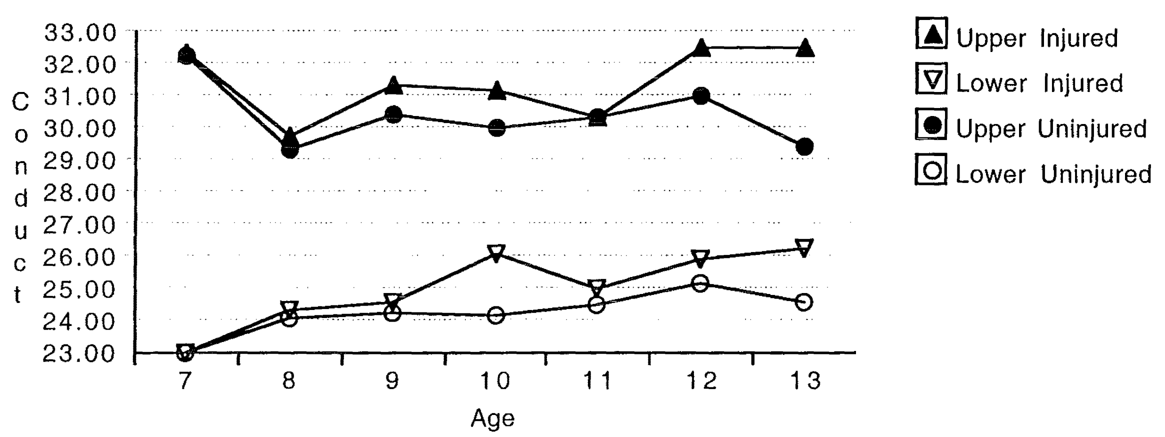

Figure 25. Combined Mothers/Teachers conduct ratings, 0-10 injury/non injury groups matched: Median split.

median split, are shown as combined scores in Figure 28. As with the 0-10 group, children who were initially rated highly in both the injury and non injury groups, have similar scores across the 7 years of testing with a general downward trend being apparent. However, a different pattern emerges for children who were initially rated as having low scores on measures of attention. Scores for these children show an upward trend in comparison to the children in the reference group. Similar trends were apparent for both mother and teacher ratings as shown in Figures 26 and 27 respectively.

Combined mother and teacher ratings of conduct for children in the 0-5 year group are shown in Figure 31. While conduct scores for children in the reference group appear relatively static, children in the head injury groups, regardless of initial scores, show an upward trend. This is even more mark for teacher ratings of conduct for the 0-5 year injury group (Figure 30). Children in the head injury group scored higher on teacher ratings of conduct in almost every year. For teacher ratings, the most marked increase in problems is evident in the children in the head injury group who had initially scored in the high range. For mother ratings of conduct, the increase in problem ratings is most evident for children who initially had lower scores (Figure 29).

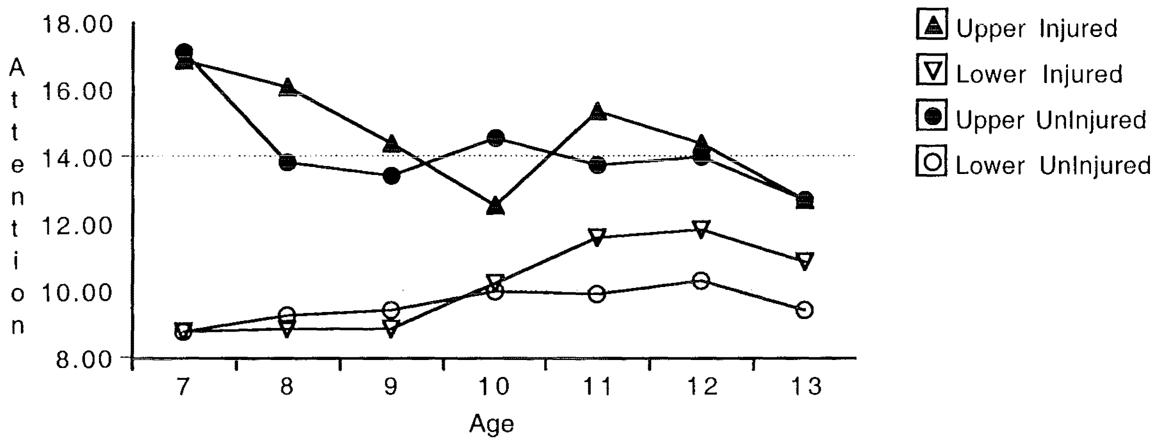

Figure 26. Mother attention ratings, non-injury subgroup matched to 0-5 injury group: median split

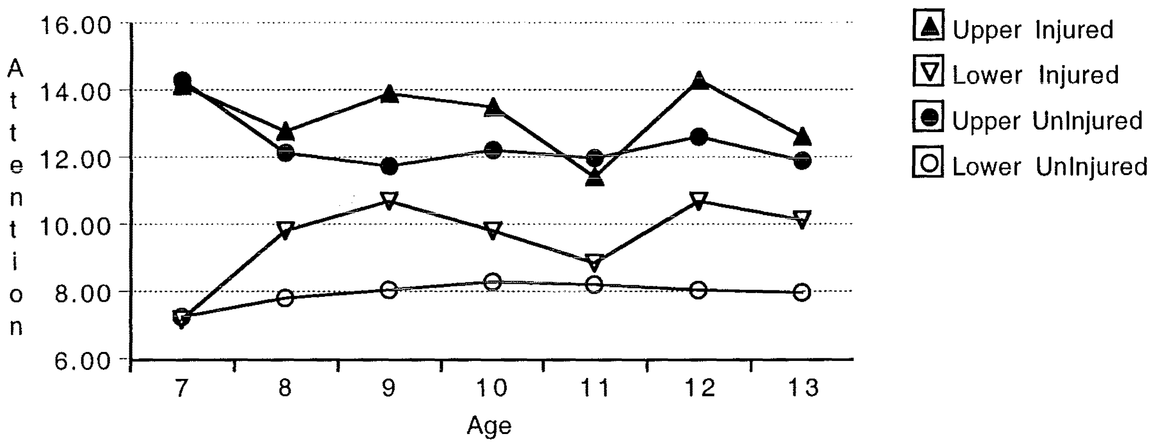

Figure 27. Teacher attention ratings, non-injury subgroup matched to 0-5 injury group: median split

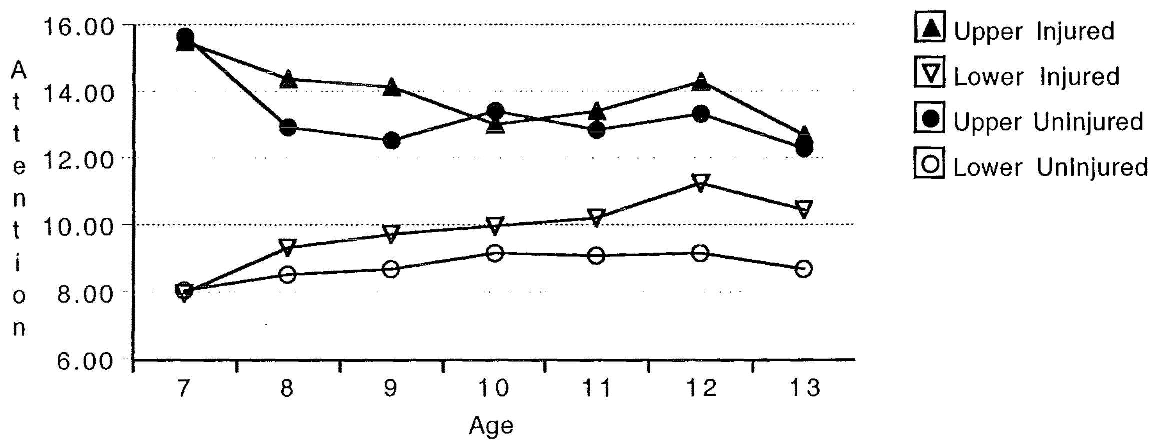

Figure 28. Combined Mother/Teacher attention ratings, 0-5 injury/non-injury subgroups matched: median split

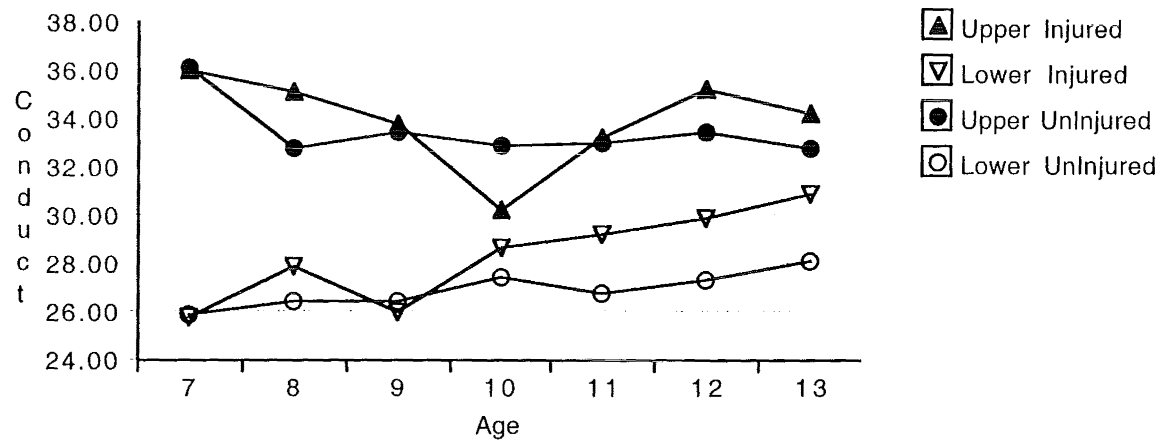

Figure 29. Mother conduct ratings, non injury subgroup matched to 0-5 injury group: median split

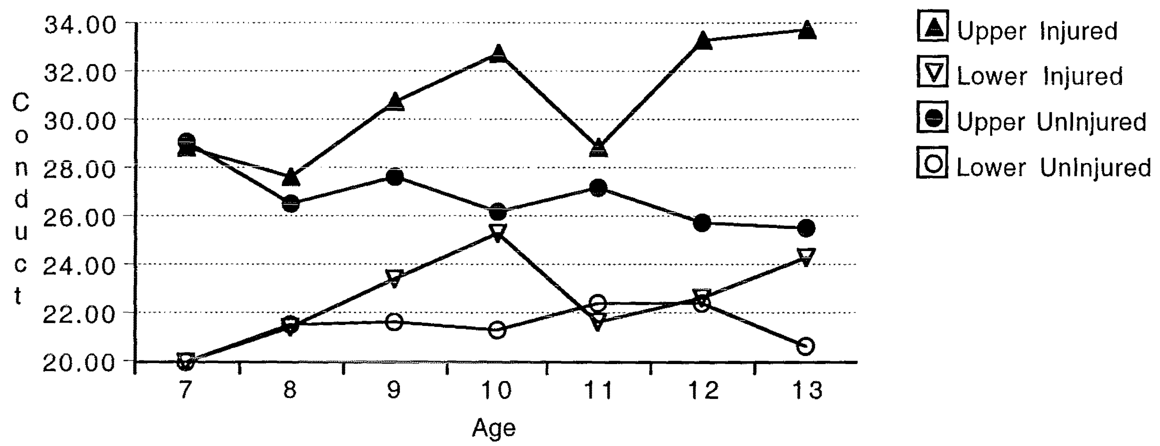

Figure 30. Teacher conduct ratings, non injury subgroup matched to 0-5 injury group: median split

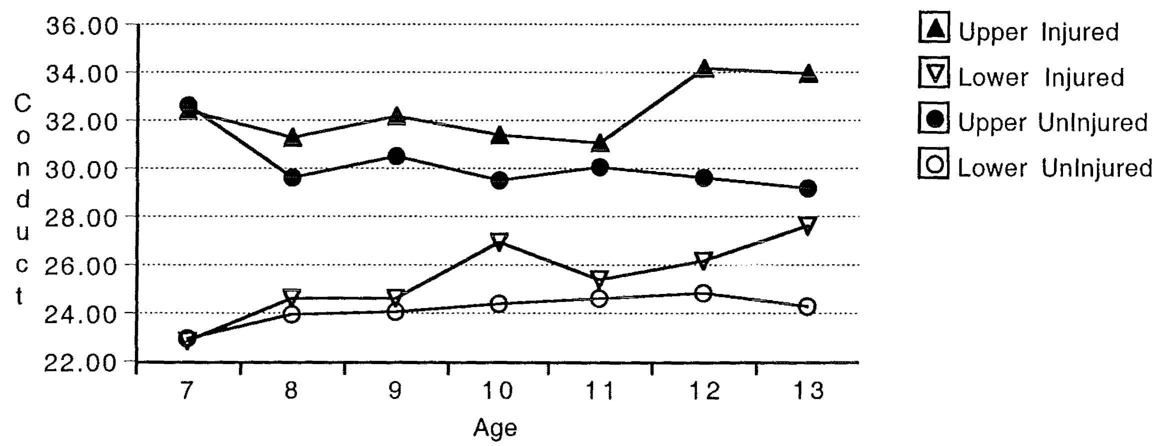

Figure 31. Combined Mother/Teacher conduct ratings, 0-5 injury/non injury matched subgroups: median split

4.1 Discussion

4.1.1 Brief Recap of Previous Literature

Mild head injury is a frequently occurring event during childhood and over the past 20 years there has been increasing research interest in this area in an effort to define the nature of possible deficits associated with this type of injury. To date, there has been a lack of consistency in reported outcomes, with potential the deficits considered and the measures used to test them being numerous. Further, there have been few replications in the research on which to base any firm conclusions regarding whether mild head injury results in any reliably measured outcome. The inconsistencies in the literature are likely to be related to number of methodological difficulties associated with research in this area. Currently there is no accepted definition of mild head injury and studies have varied widely in their inclusion criteria. Also, many studies have used small sample sizes, lacked standardised measures and have used varying periods of follow up. In a review of available literature from 1975 to 1995, Satz et al. (1997) stated that only three of the studies reviewed met all six criteria that they considered to be a requirement for a methodologically strong research design.

Given that children are in the process of development, and that any deficits associated with mild head injury will be super imposed on the developmental process, one of the most important weaknesses in the literature to date is the lack of research encompassing a longitudinal design. The primary purpose of this study was to examine outcomes following mild head injury in childhood while overcoming a number of the major methodological short comings present in previous research. It was hypothesised that children who had experienced a mild head injury would be more likely to exhibit behavioural problems and to demonstrate greater deficits in cognitive functioning, when compared with the children in a reference group.

4.1.2 Findings of The Current Study

One major research hypothesis of the current study, which received clear support, was that head injured children would demonstrate higher levels of behaviour problems, as measured by parent and teacher ratings of attention and conduct. The results of this current study supported the research hypothesis. Children between the ages of 0-10 who experienced a mild head injury of sufficient severity to warrant hospitalisation, were more likely to show increased behavioural problems as rated by both parents and teachers. Interestingly, this adverse outcome was not evident in children with presumably less traumatic mild head injury, that is the outpatient group.

Stronger associations were related to early injury, with children who were injured prior to age five being more likely to show increased behaviour problems than those injured between the ages of 6 and 10.

Moreover, the findings indicated a direct relationship between head injury status and increased problems with attention and conduct. As the children used in this study were part of a longitudinal birth cohort, multiple measures were available to assess the possible relationship between head injury status and a wide variety of child and family characteristics that could be potentially related to observed outcomes, rather than mild head injury. As stated previously, several variables to be used as covariates, these were selected from a large set of non-injury variables (see Table 3-5). A lenient criterion was used in the selection of these variables to err on the side of explicitly ruling out the influence of potential confounds in the analyses of the effects of mild head injury. Even using this cautious approach, initial findings remained after being adjusted for a wide range of possible confounding factors.

Another area of interest was the possible relationship between mild head injury and an increased occurrence of psychiatric disorders. A strong association between head injury status and the development of a psychiatric disorder was found. This was especially marked among children who had experienced a mild head injury prior to age five and had required inpatient care. Adjusted odds ratios indicated that these children were over 4 times more likely to develop behaviours consistent with ADHD, over 5 times more likely to develop CD/ODD and over 9 times more likely to demonstrate behaviours associated with substance abuse/dependence. A weaker pattern emerged for the group containing all the children injured between 0-10 years. Odds ratios indicated that children who had required inpatient care in this group were nearly 3 times more likely to have behaviours consistent with ADHD, over two times more likely to have behaviours associated with CD/ODD, and over 4 times more likely to exhibit behaviours consistent with substance abuse/dependence. Max et al. (1997) also reported an increased occurrence of ADHD and CD/ODD following mild head injury.

It was also expected that children who experienced a mild head injury would exhibit deficits on measures of cognitive and academic performance. However, there was no support for this expectation from the present study using a range of standardised measures of cognitive and academic performance. Children in the head injury groups were indistinguishable from the reference group, irrespective of age at injury or mild injury severity, on measures of cognitive and academic performance.

4.1.3 Methodological Strengths of the Current Study

It is pertinent to consider methodological strengths or weaknesses of the current study. Methodological concerns may temper or strengthen any conclusions drawn and the generality of the findings reported. Satz et al. (1997) identified six characteristics which they suggested were essential for a strong methodological design when examining outcomes following mild head injury in childhood. These characteristics were: a control group, longitudinal follow up, clear definition of what constitutes a mild head injury, standardised tests, consideration of pre-injury characteristics and a sample size of greater than 20. Each of these elements of a strong methodological design will be examined in relation to this current study

As this current study used a birth cohort constituting a large longitudinal epidemiological study, a large reference group was available as a comparison for the head injured children. The use of a reference group overcame the difficulties associated with a lack of controls and with the use of an other injury control group in that it provided a larger and more representative sample of children of similar age, educational and social circumstances to those head injured. In contrast, no controls were used in over half the studies reviewed (see Table 1), making it difficult to evaluate whether reported outcomes could be attributed to head injury status or other factors associated with characteristics of the child and family. Other studies have used 'other injury' controls (Asarnow et al., 1995; Bijur et al., 1990; Overweg-Plandsoen et al., 1999), however, the extent to which children who have had potentially painful and distressing injury, such as burns and fractures, can be compared to a child with a mild head injury is doubtful.

A further advantage of this cohort is that it provided a large sample size of mild head injured children, with 134 children in the cohort meeting the criteria for mild head injury. Many previous studies have used small sample sizes, reducing their power to detect possibly subtle effects of mild head injury; a factor which may have contributed to the inconsistent findings in the area. Of the studies reviewed, less than half had sample sized greater than 20, with only 12 having sample sizes greater than 50 (see Table 1).

A major difficulty with research in this area is the lack of a clear definition for mild head injury. In this current study, not only was a clear definition of mild head injury used to identify children who had experienced a mild head injury, a further strength of this study was the setting of a lower head injury criteria, as suggested by Kibby and Long (1996), to ensure that all the children included in the head injury group did in fact experience a mild head injury. Over the 10 years of the cohorts life, there were 525 incidence of injuries to the head experienced by the children. The majority of these injuries (n = 389) were superficial and therefore excluded by the lower criteria of the study. The requirement of the study was that the injury be of sufficient severity for medical attention to be sought and to warrant a diagnosis of concussion or suspected concussion. Previous studies have failed to set lower limits and this may account some of the inconsistency in findings (e.g., Andrews et al., 1998; Casey et al., 1986; Mitternberg et al., 1997).

This present study has used a longitudinal design, with outcomes being examined between 6-16 years post injury. This enabled the detection of any problems that emerged as the children reached adolescence. As children are in the process of development, a longitudinal design is essential to fully appreciate the impact of what may initially see to be a minor impairment. To date, only one study has examined outcomes into adulthood for individuals who sustained a head injury during childhood. Outcomes from this study suggest that continuing problems may exist (Klonoff et al.,1993). Animal research suggests that the full impact of brain damage may not be completely apparent until maturity is reached (Kennard, 1942). As can be seen in Table 1, only seven other studies have examined outcomes for children more than five years post injury. Therefore, the possibility of detecting problems emerging over time would have been diminished for the majority of previous studies.

Outcome measures used in this study were either based on, or used, standardised measures, including the WISC-R and the Rutter and Conners Behavioural scales. Satz et al. (1997) identified the lack of standardised measures as a major weakness of research in the area of mild head injury. To date, studies examining outcomes following mild head injury have used a wide range of measures, many of which have not been standardised, making comparison between studies difficult and possibly contributing to the inconsistent findings in this area.

Satz et al. identified a lack of follow-up as a methodological flaw in previous research. In contrast, information on the children in this current research has been gathered prospectively on a regular basis since birth. Thus, multiple assessment periods have been available to examine possible outcomes associated with mild head injury, enabling the detection of deficits at different time periods following injury, a prospective longitudinal design. However, as can be seen in Table 1, nearly half of the previous studies reviewed have used a cross sectional design which may be problematic. Most importantly, as a cross sectional design examines functioning at a single point in time, it is less likely to detect deficits which may emerge over time. Further, research suggests that deficits will be specific to the age at which the child is injured (Barnes et al., 1999; Wrightson et al., 1995). Therefore, the detection of deficits would required consideration of the skills that were emerging at the time of injury. However, most previous research have used general neuropsychological measures to detect the presence of any deficits (as can be seen in Table 1), and, given this, it is less likely that a cross sectional design using these general measures will detect any age specific deficits which might be associated with mild head injury functioning.

A unique feature of this study in that children in the mild head injury group were not treated as a homogeneous group. The current study examined the effects of mild head injury on the basis of suspected severity (inpatient vs outpatient) and developmental age at the time of injury (0-10 years; 6-10 ;years and 0-5 years). Children who experienced milder injuries were indistinguishable from the reference group on all measures regardless of age at injury. Asarnow et al. (1995) has suggested that there may be lower limits for which the effects of mild head injury may not be detected, this study supported that assertion. The lack of deficits in the outpatient group also supports the suggestion by Kibby and Long (1996) that it is essential for studies to set a lower head injury criteria. Previous studies have failed to set lower limits and this may account some of the inconsistency in findings (e.g., Andrews et al., 1998; Casey et al., 1986; Mitternberg et al., 1997).

To lessen the chance of potential informant bias, information for this present study was gathered from multiple informants, both parents and teachers, and across the multiple situations of both home and school. It has been suggested that parents may report increased behavioural problems following head injury due to preconceived ideas about possible outcomes that they may associate with head injury, or as a result of over reacting to the stress of the injury itself (Casey et al., 1986). However, one of the main findings of this study was a clear relationship between mild head injury in childhood and problem behaviours, when assessed in terms of increased ratings for both mothers and teachers on measures of attention and conduct.

Thus, the current study not only met the six essential criteria outlined by Satz et al. (1997), but exceeded their criterion by having available prospectively collected information, use of a lower inclusion criteria for the mild head injury group and dividing the group in terms of injury severity and the use of multiple informants to collect information on the child's functioning.

4.2 Contribution of the Current Study and Relevance to Previous Research

4.2.1 Behavioural outcomes

The positive findings presented here may be related to the unique characteristics of this study. This is the first study to use a longitudinal cohort to focus on behavioural outcomes in children who experienced a mild head injury prior to age five. Also, as mentioned previously, this study was unique in that the children in the mild head injury group were analysed both in terms of injury severity and age at the time of injury. Children who experienced milder injuries were virtually indistinguishable from the reference group on all measures.

This study highlights the possibly special vulnerability of children under 5 years old in relation to behavioural outcomes. When the children in the cohort were analysed in terms of age at the time of the first injury, behaviour problems were clearly evident in children who were younger at the time they experienced the head injury. Further, rather than remaining static or improving, consistent with the theory of a recovery curve, the children in the 0-5 year group where more likely to demonstrate increasing behaviour problems as they matured.

This is the first study to use a longitudinal cohort to focus on behavioural outcomes in children who experienced a mild head during the pre-school years. While a number of studies have included under 5 year old's in their samples, only three studies prior to this one have focused on outcomes for children who experience a mild head injury prior to age 5 (Ewing-Cobbs et al., 1989; Lyons & Matheny, 1984; Wrightson et al., 1995). Only one of these studies focused on behaviour as a possible outcome. Lyons and Matheny (1984) examined outcomes for 13 pairs of male monozygotic twins, one of each having experienced a mild head injury prior to 48 months of age (defined as experiencing a non compound skull fracture). Five of the children experienced their injury between 12 and 36 months of age and 8 between the ages of 36 months and 48 months. When the children were 6 years of age they were administered the Wechsler Preschool and Primary Scale of Intelligence (WPPSI). Also, parental ratings of behaviour were taken based on six factors of personality and temperament; compliance morality, applied cognitive, sociability, emotionality, tough-mindedness and activity-distractibility. Lyons and Matheny (1984) provide some support for the current findings, reporting evidence of increased emotionality. The emotionality scale included the following descriptions, slow-to-discipline, excitable, grouchy, moody, tense, emotional, and quick tempered. Michaud, Rivara, Jaffe, Fay, & Dailey, (1993), also reported increased likelihood of behaviour problems among a group of the children receiving special education services, 88% (14/16) of whom had experienced a mild head injury prior to age five. The increasing behaviour problems reported by parents and teachers in this current study may be related to the progressive expectation as the child matures of increasing self regulatory skills, associated with developing frontal lobe functions, that the head injured children were less able to meet (Welsh, Pennington & Groisser, 1991).

Behaviour problems were less evident for children who experienced a head injury between 6 and 10 years of age. The only significant finding for this study, after adjusting for potential confounds, was attention problems reported by the child's teacher for children who had required inpatient care. Two other longitudinal cohorts have examined outcomes for children of a similar age. Bijur et al. (1990) also reported an increase in hyperactivity for children who had experienced a mild head injury between the ages of 5 and 10, and, as with this present study, this increase in behaviour problems were evident in terms of teachers but not mothers ratings. On the other hand, Godfrey (1999) failed to find a relationship between an increase in behaviour problems and mild head injury for children aged between 7 and 12 years. The children in this current study, and in the study conducted by Bijur et al. (1990), experienced their head injury between the ages of 5 and 10 years, whereas over half of the children in the Godfrey (1999) study were between 10 and 12 at the time of their head injury. This difference in the ages of the children at the time of injury may perhaps explain the discrepancy between the three studies.

Consistent with the findings reported in this study, behavioural outcomes have been reported by a number of authors (e.g., Andrews et al., 1998; Asarnow et al., 1991; Casey et al., 1986). However, the current findings are in stark contrast to a number of other studies that have examined behaviour following mild head injury in children and failed to find any evidence of deficits (e.g., Asarnow et al., 1995; Ponsford et al., 1999; Kinsella et al., 1999). To measure behavioural deficits many previous studies have used the CBCL, a broad based screening device designed to detect psychopathology rather than the subtle behavioural changes that might be expected following mild head injury. Further, most of these studies have used relatively short post injury follow up periods, reducing the possibility of detecting behavioural deficits that may manifest over a longer time period. Both of these factors may have contributed to the inconsistency of behavioural findings following mild head injury.

4.2.2 Psychiatric Outcomes

This current study is the first longitudinal cohort to examine the possibility of psychiatric outcomes following mild head injury in childhood. The presence of psychiatric outcomes were assessed using the DSM-III-R criteria and were evaluated over the 14 to 16 year age period. The presence of psychiatric disorders, as with behavioural outcomes, were related to age at injury and severity of the injury. A strong relationship was found in this study between psychiatric disorders and mild head injury, especially for children who had experienced a head injury prior to age five. This relationship remained even after a wide range of covariates were included in the analyses. One important feature of this prospective longitudinal design is that there would be no expectation from teachers and parents that a mild head injury requiring hospitalisation would be associated with behaviours consistent with ADHD or CD/ODD or substance abuse/dependence.

Adjusted odds ratios indicated that children who experienced a mild head injury between the ages of 0-10 had an increased likelihood of developing problems with substance abuse/dependence, being over four times more likely to meet the DSM-III-R criteria. Children with the more severe mild head injuries (inpatient group) were also over 4 times more likely to engage in behaviours consistent with substance abuse/dependence. Children in that group were also almost three times as likely to develop behaviours consistent with ADHD and over two times more likely to develop behaviours consistent with CD/ODD when compared to the reference group. Ratios which just failed to reach significance after adjustment for possible confounding variables.

When the head injury group were analysed in terms of age, children in the 6-10 year old sub group were indistinguishable from the reference group except for a significant increase in mood disorders in the outpatient group. In contrast, as a group, children who had experience a head injury between 0 and 5 years of age had a significantly higher chance of developing CD/ODD and substance abuse/dependence. After covariates were added to the odds ratio analysis, children in the 0 to 5 year group who had required inpatient care were over four times more likely to demonstrate ADHD behaviours, five times more likely to exhibit behaviours associated with CD/ODD, and over nine times more likely to have a problem with substance abuse/dependence when compared to the reference group.

Psychiatric outcomes have rarely been examined following mild head injury in childhood (see Table 2). Segalowitz and Lawson (1995) reported an increase in attention deficit and depression in a group of high school students who had experienced mild head injury, but these findings were based on self report and did not take into account pre-injury characteristics. While a number of other studies have found an association between mild head injury and psychiatric outcomes, it has been suggested by a that any association can either be explained or predicted by the pre-existing characteristics of the family or the child (Brown et al., 1981; Max et al., 1997). However, both of these studies have relied on retrospective information, whereas this present study had access to information that was collected both pre and post-injury. Also, both of these these latter studies have used relatively short follow up periods and it is likely that many of the children examined had not reached the age where a number of the possible disorders, as examined in this present study, e.g. substance abuse/dependence, alcohol abuse/dependence, would have been evident.

4.2.3 Cognitive Outcomes

While a number of possible cognitive outcomes were examined in this study, none of the measures used detected any significant differences between children who had experienced a mild head injury and those children in the reference group. The lack of findings associated with cognitive outcomes was evident regardless of age at injury or its severity and was evident both before and after statistical adjustment for possible confounds. A lack of support for cognitive deficits has also been reported in a number of previous studies (e.g., Asarnow et al., 1995; Bijur et al., 1990; Godfrey, 1999). In contrast, two studies have found a clear association between a range of cognitive deficits and mild head injury. Both Klonoff et al. (1977) and Gulbrandsen (1984) reported the opposite finding to this present study. However, Gulbrandsen (1984) failed to adjust the outcomes to account any premorbid characteristics of the family or child and, as stated earlier, the study by Klonoff et al. (1977) included a number of children who had suffered more severe head injuries. These factors may have contributed to the adverse findings reported in these two studies.

4.2.4 Effect Sizes, Practical Significance and Clinical Importance of the findings

Asarnow et al. (1995) suggested that there may be no consistent deficits associated with head injuries in the very mild range. Further, that if deficits were detectable, they would have no real clinical importance. However, head injury status in this current study was clearly associated with increased behavioural problems as rated by both parents and teachers. These findings indicate that children who sustain a mild head injury may experience difficulties with social interactions in a number of settings (home and school). Further, given that childhood head injury is a frequently occurring event any findings are potentially clinically important in terms of the numbers effected.

Statistical analysis supports the clinical importance of the finding of this present study with medium to large effect sizes being found (using Cohen's d) for both mother, teacher and combined ratings for attention and conduct. The unadjusted means for the behavioural and cognitive outcomes for children in the 0-10 year group are shown on the left hand side of Table 11. As combined ratings give a more comprehensive indication of the child's behaviour across settings, these will be the focus of discussion. A large effect size is evident for combined ratings of both attention and conduct. In terms of a binomial display size effect, these effects sizes are equivalent to an increase from no problems behaviours to problem behaviours of 30.8% to 69.2%, and 30.6% to 69.4% respectively. A number of cognitive outcomes show small effect sizes, the largest of these being for School Certificate and PAT11 (scores on mathematical achievement at age 11). Small effect sizes are also evident for the Burt word reading and PAT10 (reading comprehension test) test. Adjusted means are shown on the right hand side of Table 11. While the effect sizes are reduced with the inclusion of covariates, combined ratings for attention and conduct still show a medium effect size.

The left hand side of Table 12 also displays the effect sizes associated with head injury status for children who had injuries between 6-10 years of age. As indicated previously, medium to large effect sizes are evident for all behavioural outcomes and two cognitive outcomes (Burt word reading test and PAT11, scores on mathematics achievement test). When these are adjusted for potential confounds (right hand side of Table 12), for combined ratings of attention there is a medium effect size with a small effect size for combined ratings of conduct. The two cognitive outcomes remain significant, with a large effect size evident for ratings on the Burt word reading test.

Effect sizes associated with outcomes for children who had their injury between 0-5 years of age is shown on Table 13. Unadjusted means are shown on the left hand side of the table. The combined ratings for conduct and attention indicate a medium to large effect sizes. Only one of the cognitive outcomes (School Certificate) indicates a medium effect size with the rest showing a small effect size. Adjusted means are shown on the right hand side of Table 13. A medium effect size for combined ratings of attention and conduct were evident over the assessment periods of 10-13 years and 7-13 years, with small effect sizes evident for ratings over the 7-9 year period. Small effect sizes were evident for all cognitive outcomes.

It is evident that mild head injury is associated with a substantially increased likelihood that children will exhibit problem behaviours. While unreliable increases in deficits were evident for cognitive outcomes, other findings here have major implications for educational institutions as children with mild head injuries are likely to exhibit behavioural problems and be more difficult to manage in the classroom. Also, the findings from this study suggest that the early behavioural problems may have more serious implications in adolescence as increased numbers of children who have mild head injury develop ADHD, CD/ODD and behaviours consistent with substance abuse. This was especially evident for children injured prior to age five.

The early identification of children who experience mild head injury is therefore essential to enable appropriate behavioural intervention programmes to be implemented in the classroom situation. Such intervention may preempt the future development of psychiatric disorders. Further, rather than reassuring parents of the benign nature of mild head injury, it may be appropriate to make them aware some of its possible implications and long term consequences. There are also important developmental implications for the child. As mentioned previously, Andrews et al. (1998) indicated that children with mild head injury show lower levels of self esteem and higher levels of loneliness, both of these symptoms may be related to difficulties with behavioural control associated with mild head injury.

4.2.5 Pre-injury Characteristics of the child

Considerable controversy has been generated as to whether mild head injury in childhood is associated with behavioural problems or whether children with difficult behaviour are more likely to engage in activities which result in head injury. To date only two studies have assessed behaviour of children prior to injury. Godfrey (1999) reported no evidence of pre-injury behaviour problems, while Bijur et al. (1990) reported the only significant pre-injury difference in the head injured children being increased levels of aggression. All others studies have relied on the accuracy of retrospective parental reporting for measures of base line functioning. Retrospective reporting has a number of limitations and parents may be inaccurate when asked to recall detailed aspects of their child's behaviour. Because of the limitations inherent in the reliance on retrospective reporting, information gathered in this way has not provided unequivocal support for excess of pre-injury behaviour problems in children with mild head injury. While some studies have found an excess of pre-injury behavioural problems among children who suffer mild head injuries, others have come the to the opposite conclusion (Donders, 1992; Pelco et al., 1992).

Findings from this current study indicate that children who experienced a mild head injury, regardless of their age at injury, tended to come from families who were experiencing a greater number of adverse life events. Mothers of children who experienced head injury were also more likely to be less emotionally responsive to their children and to use more restrictive childrearing practices. Mothers of children in the head injury groups in the current study were more likely to report their children as being more aggressive and difficult to manage. When the head injury group was subdivided by age, these associations were evident only in the 0-5 year old group. The finding of higher rates of aggression for children who experienced head injury was also reported Bijur et al. (1990).

While there were no direct measures for the behaviour of the children studied here prior to experiencing a head injury, measures of behaviour were gathered prospectively over a number of years. This, it possible to analyse whether patterns of behaviour for children who experienced mild head injury early in life were the same as for those children who did not experience a head injury. Research suggests that a child's general pattern of behaviour is relatively stable over time.

As patterns of behaviour are relatively stable over time it would be expected that children in the head injury and reference groups with identical ratings on measures of attention and conduct would both demonstrate similar ongoing patterns of behaviour. However, this was not the case. Increasing behaviour deficits for children who did not originally have problems was evident for children in this study using descriptive analysis suggesting that these children were not just children with behaviour problems who had had a head injury.

As described previously, the children in the inpatient head injury group (0-10) were matched with children from the reference group who had identical scores of attention and conduct at age seven. While scores of attention for children in the reference group remained steady or declined, children who had experienced a mild head injury differed depending on whether they initially had high or low attention scores. Children in the reference group who had exhibited difficulties in attention at age 7 continued to have problems. However, for the children in the head injury group who had initially showed no evidence of attentional difficulties, there was a steady increase in problem behaviours as these children grew older. In contrast to those exhibiting attention difficulties, in the case of conduct, scores for the head injured children as a whole increased, with children who had experienced head injury and initially scoring higher on levels of behavioural problems at age 7 exhibiting increasing behavioural problems with age. These patterns of attention and conduct were also present for the 0-5 year old subgroup.

The most interesting finding from the descriptive analysis was the emergence over time of increasing behaviour problems which were evident even among children who had not initially demonstrated problem behaviours. The pattern of behaviour change may indicate that children with mild head injuries have increasing difficulty exhibiting appropriate behaviours that would be consistent with their age. The ability to self regulate and inhibit behaviour are associated with the executive functions of the frontal lobe (Barkely, 1997). Given the relative vulnerability of the frontal lobe to damage after acceleration-deceleration impact, it might be expected that children who sustain head injury would exhibit greater levels of behaviour problems.

4.3.1 Limitations of the Present study and Recommendations for further research

As mentioned previously, there are a number of features of this study which make it methodologically strong. This study has used a longitudinal design, a clear definition of mild head injury, a lower exclusion criteria, and the differentiation of mild head injury severity (Inpatient, Outpatient), standardised testing, a large epidemiolgically representative reference group, consideration of pre-injury and family characteristics, and is one of the only three studies to have available prospectively collected data on these characteristics. However, there are often limitations in this field of research and so it is appropriate to consider the limitations evident in the current study.

As the children used in this study were part of a longitudinal cohort, measures currently used to define head injury such as GCS and PTA were not in common use at the time of injury, making it difficult to directly compare between the findings of this study and research using more recent measures of head injury criteria. This deficit is, however, only a minor concern, because the use here of concussion/suspected concussion of < 30 minutes is a major criterion in contemporary literature.

Another limitation of this present study is the variation in numbers of children available for each analysis. Although the overall size of the head injury group would have given the study a 98% chance of detecting an outcome for two groups using a significance level of .05 given any expectation of a medium effect size, the power of the study was reduced substantially by dividing the groups according to severity and age at injury. This was most apparent for the 6-10 year subgroup and may account for the small number of behavioural deficits detected for this group.

Further, there was no way of establishing the number of head injuries that occurred for children in the cohort between the ages of 10 and 15 years of age. It is possible that a number of the children in the head injury groups and the reference group will have experienced a head injury during this time which may have contributed to the findings presented here. However, the evidence provided here indicated that injury prior to age 5 was most important predictor of outcome.

It is also possible that a number of other factors could have contributed to the outcomes of this present study. Further information related to the characteristics of the child and family were not available prior to completion of this thesis, including information regarding injuries not related to the head. Bijur et al. (1990) found that children with head injury had had significantly more hospitalisations for other events prior to their head injury. Unfortunately those data were not available for inclusion in the current analyses.

4.3.2 Suggestions for future research

To date only a handful of studies have examined outcomes for children more than five years post injury. As childhood is characterised by change and the development of skills, any deficits associated with an injury during this period may be masked by developmental processes. Therefore, to fully appreciate the potential outcomes associated with mild head injury during childhood would require research with extended periods of follow up. To date there have been only 4 studies of this type. However, is must be acknowledged that economic and time constraints limit the extent to which this type of research can be undertaken. As an alternative to longitudinal research it may be more appropriate for future research to focus skills that are emerging at the time of injury, as opposed to the more general test batteries that are characteristic of research of this area, as these emerging skills may be more vulnerable to disruption.

This study examined the relationship between early mild head injury and behavioural and cognitive outcomes using an analysis of covariance. Given the controversy surrounding the contribution of family factors to outcomes following mild head injury, future research may examine the relative contribution of head injury as opposed to other predictors on these outcomes. To answer this different type of evaluation (i.e. different to one on mean differences), multiple linear regression can be used for continuous outcomes and the standardised regression (beta) coefficients compared for each predictor. The beta coefficients can be interpreted as the direct correlation between the predictor and outcome when all other factors in the model have been taken into account. For binary outcomes this can be done using logistic regression analysis (these relative beta weights were not reported here). Comparisons can be made with the estimated odds ratios for each predictor adjusted for all other variables in the model (personal correspondence, John Horwood, 2001).

Finally, as many studies to date have been hampered by small sample sizes, knowledge about outcomes for children following mild head injury could be enhanced by a meta-analytic review of current research.

4.4.1 Summary

A number of findings were reported in this study, most importantly a clear relationship was evident between mild head injury prior to the age of 10 and increased behavioural and psychiatric difficulties. Increased ratings on attention and conduct were evident for children in the inpatient mild head injury group. Also, a greater number of children in this mild head injury group, relative to the reference group, demonstrated behaviours consistent with a DSM-III-R diagnosis of ADHD, CD/ODD, substance abuse/dependence and mood disorders. These findings were related to age at the time of injury and the initial severity of the injury because they were clear in the 0-5 inpatient group and not evident in the outpatient mild head injury group. This is one of the only studies to have available prospectively collected data on the child and family. Taking this prospectively collected data on the child and family into account, using covariance and logistic regression analyses, relationships found between increased behavioural and psychiatric outcomes were clearly evident.

A variety of family characteristics were found to be related to head injury status, including the number of stressful life events and mothers report of the children being difficult to manage and more aggressive with other children at age 3 years old. However, mothers perceptions of the children may be related to the level of stress in the family rather than any intrinsic behavioural characteristic of the child. It is important to point out that further analyses supported the concept of head injury status being strongly related to increased behaviour problems regardless of whether the child initially exhibited an excess of externalising behaviours in both the 0-10 and 0-5 injury groups.

The findings from this study strongly suggest a relationship between mild head injury in childhood and long term adverse behavioural and psychiatric outcomes. Further, strong age effects were evident, with children who were younger at the time of injury being far more vulnerable to long term problems, a finding which does not support the concept of youthful plasticity. It should be remembered that the findings presented refer to outcomes for a group and therefore cannot be regarded as predictive for individual members of the group.

Given the findings presented here and the inconsistency in the literature, it seems premature and unduly optimistic to reassure a parent that their child's mild head injury is inevitably a completely benign event. Often a benign outcome is likely, (with most cases of mild head injury requiring outpatient care only) but this is probably not so in other instances (many of those requiring hospital observation). The task facing the medical community is to find more objective ways of identifying those cases at the time of injury who are vulnerable to adverse early life outcomes and identifying the nature of their injury that might predict such later outcomes. Another task is to recommend appropriate post-injury management regimens that might minimise such adverse outcomes.

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Study	Head injury definition	Design	Source of participants	Preinjury factors	Non head injured control group(s)	Follow-up(s)	Type of assessment	Reported outcome
Maximum period of follow up after head injury of greater than 10 years								
[1]§ Klonoff et al. (1993)	*Mild* (*n* = approx. 90% Cross-sectional of 159): not defined, based on length of consciousness, skull fractures, EEG ratings. and post traumatic seizures	Longitudinal	Consecutive admissions to hospitals	Statistically controlled	No	Interviewed 159 of the original sample of 231, 23 years post injury	Standardised interview	Adverse: Subjective sequelae in physical, intellectual or emotional domains were reported as due to the head injury by 31% of the sample. These sequelae were reported to be related to the severity of the original injury and initial IQ. The results for this study are reported for the group as a whole making it difficult to distinguish outcomes for different level of severity.
Maximum period of follow up after head injury 5 - 10 years								
[2]‡ Colantonio et al. (1998)	*Mild* (*n* = 24): GCS 13-14 & 15 with LOC or loss of memory of events immediately prior to accident or altered mental state and confirmed by CT or MRI if available *Mild -Mod*: (*n* = 27) *Moderate*: (*n* = 7) GCS 9-12 *Severe*: (*n* = 20) GCS < 9 *Age*: 15-19 yrs	Retrospective	Record review of onsecutive admissions to a large tertiary care facility from October 1988 - March 1989	Not considered	No, nomative data used as a control group	T1: 5 yr or more post injury. Administerd by phone for 47 subjects and through an informant for 4 subjects who were unable to use a phone to communicate	Standardised Quality of Life (QoL) measure: MOS-SF36, Head Injury Symptom Checklist, CIQ,	Adverse: Lower scores than normative data on all QoL measures except pain with the gratest concern for both mild and severe HI subjects being mental health. Mild HI subjects reported as many or more QoL symptoms in the previous 4 wks compared to mod-severe HI, posibly due to better insight. It was noted that lower home integration scores as measured by the CIQ for some HI subjects may not acurately reflect their true integration status as they my be living at home or may not be expected to do home tasks even though they are able.
[3] Costeff et al. (1988)	*Mild* (*n* = 23): hospitalised in local paediatric ward after head trauma *Severe* (*n* = 12): hospitalised on a neurosurgical unit (Follow-up assessment was performed in unselected samples from a larger cohort presented in Horowitz et al. (1983)	Retrospective	Previous admissions to emergency room	Not considered	No	T1: 3.5 - 10.0 yr follow up	Neuropsychological: Bender-Gestalt Copying. Test, Benton Visual Retention Test, and four WISC-R sub tests	Null: Although these results did not show any impairment in the mild group, the results were weakened by the small and potentially biased samples at follow up as well as by the limited assessment battery used., it is unclear what the basis was for follow up and whether it was the same for each group

Study	Head injury definition	Design	Source of participants	Preinjury factors	Non head injured control group(s)	Follow-up(s)	Type of assessment	Reported outcome
[4]‡ Godfrey (2000)	*Mild* (*n* = 38): Evidence of blow to head and medical intervention sought and either 2 or more concussion symptoms or injury described as concussion or suspected concussion. Hospitalised < 24 hr	Longitudinal	Dunedin Multi-Disciplinary Health & Development Study	Exclusion criteria: Hx neurological abnormality, Hx of HI, pre injury characteristics statistically controlled	Other injury & No injury controls	T1: 3 yr pre injury T2: 5 yr pre injury T3: 7 yr pre injury T4: 1-6 yr after injury	Teacher & Parent Child Behaviour questionnaire, WISC-R, Rey Osterreith Complex Figure Test, RAVLT, Trail-Making Test, Grooved Pegboard, WSC, Verbal Fluency Test	Null: Neuropsychological measures: no deficits reported on any neuropsychological testing. Apart from significantly more males in the MHI groups, children did not significantly different from children with fractures or children with no injuries on any family or personal premorbid variables. Psychosocial: no difference between the groups on post post injury behaviour as rated by parents and teachers.
[5] Horowitz et al. (1983)	*Mild* (*n* = 154): at local paediatric hospitalisation with a head injury *Severe* (*n* = 26): required neurosurgical hospitalisation *Ages:* 0-7 at injury; 50% of 370 cases (original sample) were available for follow-up	Retrospective	Chart review of hospital patients	Not considered	No	T1: 4-10 yr post injury	Psychosocial: telephone survey focused on physical symptoms, school adjustments, and placement	Adverse (mild): Results showed an elevated rate of symptoms (headaches, dizzy spells, and bed wetting) and school adjustment problems; only 63% of the mild group were in the normal range for scholastic progress; inadequacies of case definition, lack of controls for preinjury risk factors or post injury non injured comparisons, and subjective assessment method weakened results
[6] Jordan et al. (1992)	*Mild* (*n* = 14): GCS > 8 (but 93% had GCS 13) at injury: *Age*: 5-13 yr	Cross-sectional	Previous admissions to paediatric hospital	Exclusion criteria: presence of intellectual handicap, neurological disease, or speech-language impairment prior to the injury	Yes (n = 14)	T1: 10 yr post injury	Neuropsychological (language): TOAL-2. NCCEA, and BNT	Null: No differences on any of the language measures between the mild and other-injury group; results do not address the effect of MHI on more comprehensive language measures during the first yr post injury
[7] Kewman et at. (1992)	*Mild* (*n* = 21): GCS 13-15 *Moderate* (*n* = 10): GCS 9-12 *Severe* (*n* = 21): GCS <9	Cross-sectional	Neuropsychology service	Exclusion criteria: previous brain insult or organicity	No	T1: 1-72 mo post insult	Neuropsychological: WISC-R Academic: WRAT-R	Indeterminate*

Table 1. *(continued)* Methodological Characteristics of Studies of MHI in Children and Adolescents (1970–2000)

Study	Head injury definition	Design	Source of participants	Preinjury factors	Non head injured control group(s)	Follow-up(s)	Type of assessment	Reported outcome
Maximum period of follow up after head injury 1 - 5 years								
[8]‡ Andrews et al. (1998)	*Mild* (n = 8):LOC < 20 mins. GCS 13-15 and PTA ≤ 1 hr. *Moderate*(n = 9): LOC greater than 20 mins, GCS 9-12, PTA < 1 day. *Severe*(n = 10): LOC greater than 24 hr, GCS < 8 and PTA > 7 days. *Age*: 6.6-17.8y	Cross sectional	Hospital admissions	Hx of previous HI or neurological insult, evidence of abuse or neglect, psychological disorder, LD & any other developmental disorder	Yes (matched for sex, age and SES to 27 children recruited from local schools)	T1: > 6 mo, mean T# of 1.4 yr (mild) to 1.5 yr (severe)	Semi-structured interview with child & caregiver Behavioural assessment: VABS, DeBlois aggressive and antisocial Behaviour Scale Coopersmith Self Esteem Inventory Children's Loneliness Scale.	Adverse findings: HI children showed significantly lower levels of self esteem and adaptive behaviour, and higher levels of loneliness, maladaptive behaviour and aggressive/antisocial behaviour. Weakness, no consideration of preinjury characteristics & small sample size.
[9]§ Asarnow et al. (1991)	*Mild* (n = 10): PTA < 4 hr, no coma or only transient LOC *Age*: mean 7.6 yr *Severe* (n = 11): LOC > 9 days *Age*: mean 6.9 yr	Retrospective	Outpatient paediatric treatment centre	Exclusion criteria: Hx of CNS insult or disease, development delay, or behavioural problems	No	T1: at least 1 yr post accident; M = 3.7 yr for the mild and 2.2 yr for the severe groups	Psychosocial: CBCL and VABS	Adverse (mild): showed excessive rate of behaviour problems only on the CBCL; results should be viewed with caution, given the small sample sizes and the absence of an other-injury control group to ensure that the behaviour problems were specific to head injury; Asarnow et al. (1995) have recently suggested that recruitment of mild cases from a rehabilitation hospital may have biased the selection toward more moderate injuries
[10]‡ Barnes et al. (1999)	*CHI* of sufficient severity to warrant hospital admission (n = 55): (40% GCS of 13-15 and 40% GCS < 8). *Age*: 1 yr 4 mo -15 yr 8 mo	Cross-sectional	Recruited from hospital database	Exclusions: HI as a result of abuse, Hx of developmental delay or academic, emotional or attentional difficulties	No	T1: 7 mo - 9 yr 9 mo after injury, mean 3 yr	Word Identification and Passage Comprehension from the Woodcock Reading Mastery Test-Revised.	Adverse: Difficulties with word decoding and reading comprehension skills. Age effects: Children differentially affected depending on age at injury. Children < 6.5 yr most at risk for difficulties in acquiring reading decoding skills. Weaknesses of the study includes wide variation between injury and time of testing and range of HI severity.

Table 1. *(continued)* **Methodological Characteristics of Studies of MHI in Children and Adolescents (1970–2000)**

Study	Head injury definition	Design	Source of participants	Preinjury factors	Non head injured control group(s)	Follow-up(s)	Type of assessment	Reported outcome
[11]§ Bijur et at. (1990)	*Mild*: (*n* = 114): ICD-9 code of concussion or LOC and no more than 1 night of hospitalisation *Age*: 5-10 yr	Prospective	Sub sample of a 1970 British birth cohort	Statistically controlled: Scores (at Age 10) were adjusted for intelligence, aggressive and hyperactive behaviour; at Age 5, gender, socioeconomic status. and six additional social factors	Yes (design included participants with no injury, n = 1,374), bums (n = 107), fractures (n = 466), and lacerations (n 504)	T1: Age 5 (prior to the index injury) T2: Age 10 (I-5) yr post injury)	Neuropsychological: British Ability Scale, mathematics. and reading Psychosocial: Rutter Child Behaviour Questionnaire and Conner's Parental Questionnaire	Neuropsychosocial: No differences between the MHI and no-injury group was found when adjustments were made for potential pre-accident risk factors; however, the battery did not include more sensitive measures (e.g., tests of sustained and divided attention and psychomotor speed) Academic: No differences between groups in math or reading ability after the scores were adjusted for prior risk factors Psychosocial: After parents' and teacher's ratings were adjusted for prior risk factors, the teacher's rating of hyperactivity was .4 SD higher than the M of the other-injury groups
[12] Black et al. (1970)	Only children suffering LOC, skull fractures, or neurological effects were included; severity was not subdivided	Prospective	Consecutive admissions to hospital	Statistically controlled	No	T1: during hospital admission T2: 3 mo T3: 1 yr T4: 2 yr T5: 3 yr T6: 4 yr T7: 5 yr	Neuropsychological: WISC Psychosocial: looked for signs of post traumatic syndrome	Indeterminate*
[13]§ Brown et al. (1981)	*Mild* (*n* = 29): PTA > 1 hr and < 1 wk *Severe* (*n* = 31): PTA ≥ 7 days *Age*: 5-14 yr	Prospective	Hospital admissions	Controls "closely comparable" on attributes expected to relate to preinjury intellectual and scholastic ability	No matched controls for the mild group	T1: recovery from PTA T2: 4 mo T3: 1 yr T4: 2.25 yr post injury	Neuropsychological: WISC, Paired Associate Learning. Object Naming. Verbal Fluency, Continuous Performance Test, Stroop test, Matching Familiar Figures (mild cases were given more limited testing, only six sub tests from the WISC) Academic: Neale Analysis of Reading Ability	Null Neuropsychological: Mild group showed lower WISC PIQ (vs. controls for severe group) at each follow-up assessment, with virtually no recovery; they concluded that the effects of the MHI was negligible and largely due to pre-accident risk factors, including low IQ; however, results should be viewed with caution due to the lack of a matched control group for the mild group and the use of only WISC sub tests, which may be too brief and global a measure to be sensitive to changes in attention, memory, and psychomotor speed Academic: Approximately 40% of the mild group showed a high rate of reading backwardness throughout the duration of the follow-up; they concluded that a lack of recovery pattern precluded attributing poor performances on the reading test to the effects of the head injury; however, use of a more rigorous selection method that controls for preinjury risk factors in each injury group and control groups for each injury severity level would strengthen results

Study	Head injury definition	Design	Source of participants	Preinjury factors	Non head injured control group(s)	Follow-up(s)	Type of assessment	Reported outcome
[14] Butterbaugh et al. (1993).	*Mild-mod* (*n* = 13): GCS > 8 (M 13.9) *Severe* (*n* = 9): GCS 3-8	Prospective	Trauma centre	Exclusion criteria: Hx of retardation or neurological disorders	Yes (n = 25)	T1: 1 mo post injury T2: 18 mo post injury	Neuropsychological: WISC-R or WAIS-R Academic: WRAT-R and GORT	Null: Mild CHI was pooled with moderate CHI group for analysis; initial effect at 1 mo between mild-mod and control group on 24 tests (F1Q and PIQ), which disappeared at 18 mo; difference not clinically significant (initial mild-mod: PIQ = 96, F1Q = 98)
[15]§ Chadwick et al. (1981)	*Mild* (*n* = 29): PTA > 1 hr and < 1 wk *Severe* (*n* = 31): PTA ≥ 7 days *Age*: 5-14 yr	Prospective	Hospital admissions	Controls "closely comparable" on attributes expected to relate to preinjury intellectual and scholastic ability	No matched controls for the mild group	T1: recovery from PTA T2: 4 mo T3: 1 yr T4: 2.25 yr post injury	Neuropsychological: WISC, Paired Associate Learning. Object Naming. Verbal Fluency, Continuous Performance Test, Stroop test, Matching Familiar Figures (mild cases were given more limited testing, only six sub tests from the WISC) Academic: Neale Analysis of Reading Ability	Null Neuropsychological: Mild group showed lower WISC PIQ (vs. controls for severe group) at each follow-up assessment, with virtually no recovery; they concluded that the effects of the MHI was negligible and largely due to pre-accident risk factors, including low IQ; however, results should be viewed with caution due to the lack of a matched control group for the mild group and the use of only WISC sub tests, which may be too brief and global a measure to be sensitive to changes in attention, memory, and psychomotor speed Academic: Approximately 40% of the mild group showed a high rate of reading backwardness throughout the duration of the follow-up; they concluded that a lack of recovery pattern precluded attributing poor performances on the reading test to the effects of the head injury; however, use of a more rigorous selection method that controls for preinjury risk factors in each injury group and control groups for each injury severity level would strengthen results
[16] Chapman et al. (1992)	*Mild-mod* (*n* = 10: GCS > 8 (7 had GCS ≥ 13 but were pooled with others) *Severe* (*n* = 9): GCS ≤ 8	Cross-sectional	Consecutive admissions to neurosurgery service in hospitals	Exclusion criteria: no prior diagnosis of LD or other neuropsychiatric disorder and no evidence of child abuse	Yes (n = 20)	T1: 1-5 yr post injury	Neuropsychological: focused on language, including narrative discourse, vocabulary sub test (WISC-R), and the CVLT	Null: Mild-mod group did not differ the control group

Table 1. *(continued)* **Methodological Characteristics of Studies of MHI in Children and Adolescents (1970–2000)**

Study	Head injury definition	Design	Source of participants	Preinjury factors	Non head injured control group(s)	Follow-up(s)	Type of assessment	Reported outcome
[17]‡ Dennis et al. (1995)	*CHI* of sufficient severity to warrant hospital admission. GCS 3-15	Cross-sectional	Hospital admissions	Not considered	No	Average 3.5 yr	WISC and GDS (used to generate a number of attentional tasks).	Adverse: HI sample showed poor selective and focused attention in relation to age norms. Only 3.8% of head injured children rated as having intact attentional skills. Age effect: younger group tended to perform more poorly in relation to age norms on selective attention tasks than older group. The study was weakened by presentation of the outcome information for HI group as a whole and there was a lack of control for preinjury factors.
[18]‡ Ewing-Cobbs et al. (1998)	*Mild-Mod*($n = 28$): impaired consciousness < 24 hr. *Severe* ($n = 33$): impaired consciousness ≥ 24 hr *Age*: 5-15 yr	Longitudinal	Hospital admissions	Exclusion criteria: no Hx of HI, no indication of developmental delay or learning disabilities	No	T1: after PTA, average 21 days T2: 6 mo T3: 12 mo T4: 24 mo	Peabody Individual Achievement Test; 3 sub tests of WRAT; spelling, word recognition, arithmetic	Null: Study was designed to compare HI outcomes for different levels of severity. Children with severe injuries had significantly lower academic scores compared to the mild and moderate group at baseline. This improved by 6 mo follow up.
[19]‡ Kinsella et al. (1999)	*Mild* ($n = 29$): LOC less than 20 min, GCS ≥ 13 without subsequent deterioration, no focal neurological deficits (by CT) *Moderate* ($n = 10$): GCS 9-12 without subsequent deterioration or a higher GCS with evidence of neurological deficit or CT abnormality Severe ($n = 12$): GCS of ≤ 8 on admission or within the first 24 hr *Age*: 5-15 yr	Longitudinal	Consecutive hospital admission	No previous Hx of head injury, no neurological disorder or psychiatric dysfunction	No	T1: 3mo T2: 1yr T3: 2yr	CBCL, general health questionnaire, Family Assessment Device	Null: Children with mild & moderate HI did not show a greater incidence of behavioural problems. Severe injury was associated with a greater incidence of behaviour problems. Coping sources of the family were predictive of child's outcome.

Table 1. *(continued)* Methodological Characteristics of Studies of MHI in Children and Adolescents (1970–2000)

Study	Head injury definition	Design	Source of participants	Preinjury factors	Non head injured control group(s)	Follow-up(s)	Type of assessment	Reported outcome
[20]§ Klonoff et al. (1977)	*Minor*: suspected but unproved LOC and no concussion *Mild*: suspected but unproven LOC and concussion *Moderate*: LOC < 5 min and concussion *Severe*: LOC 5-30 min and concussion or skull fractures *Serious*: LOC > 30 min and skull fractures or other sequelae *Age*: (n = 131 ≤ Age 9), (n = 100 > Age 9)	Prospective	Consecutive admissions to hospital	Not considered	Yes	T1: during hospital admission T2: 1 yr T3: 2 yr T4: 3 yr T5: 4 yr T6: 5 yr	Neuropsychological: Reitan-Indiana, WISC-R, and Stanford-Binet Academic: school placement	Adverse: At initial follow up differences were evident between HI groups and controls on 28 of the possible 32 neuropsychological variables for the younger group and 42 out of 48 for the older group. 23% of the children still showed residual impairment on neuropsychological test at the 5 year follow up. Results weakened by presentation of results for the HI group as a whole making in impossible to distinguish outcome for different levels of severity.
[21] Levin & Eisenberg (1979b)	*Grade 1* (n = 23): conscious on admittance, only momentary LOC, no neurological deficits *Grade 2* (n = 7): LOC <24 hr or neurological deficit *Grade 3* (n = 15): LOC > 24 hr	Cross-sectional	Neurosurgical service in hospital	Exclusion criteria: Hx of neuropsychiatric disorder or inability to cooperate with the neuropsychological assessment	No	T1: Grade 1 *Mdn* 28 days (2 - 1,157); Grade 2 *Mdn* 22 days (1 - 440)	Neuropsychological: WISC-R, aphasia screening, visuospatial and visiomotor abilities, memory (Bushke), and somatosensory perception	Adverse (mild): a small number of outliers (typically 7- 10%) on tests; no information about whether these proportions exceeded those expected for each test's normative group; without a non injured control group and a follow-up assessment, it is difficult to determine whether initial effect existed and whether it remitted over time
[22] Lundar & Nestvold (1985)	*Mild* (n = 118): PTA < 24 hr, Ages 1 -19 *Severe* (n = 8): PTA > 24 hr	Prospective	Patients with a head injury as a result of a traffic accident	Not considered	No	T1: 3 mo T2: 1 yr T3: 5 yr	Academic-psychosocial: Parents were questioned about complaints, school performances, and seizures	Adverse: Results showed owed that the rate of children and adolescents without any subjective complaints improved with time, being 35%, 61%, and 75% at 3 mo, 12 mo, and 5 yr, respectively; however, approximately 25% continued to report complaints 5 yr later in this predominantly mild sample Age effect: Younger children were judged to have fewer complaints and a more rapid recovery in the first 3 mo

Study	Head injury definition	Design	Source of participants	Preinjury factors	Non head injured control group(s)	Follow-up(s)	Type of assessment	Reported outcome
[23]§ Lyons & Matheny (1984)	Cotwin method, largely unselected, predominantly mild cases (non compound skull fractures); 10/13 twins were unconscious for 1 hr and hospitalised for ≤ 1 day, 2 were unconscious for 1 hr and hospitalised for 2 days, and 1 twin was unconscious for 24 hr and hospitalised for 14 days; *Age*: 5 younger children 1-3 yr; 8 older children 3-5 yr	Cross-sectional	Louisville Twin Study	Not considered	Yes (uninjured twin)	T1: Age 6 (1 -5 yr postoperatively)	Neuropsychological: WPPSI Psychosocial: parental ratings	Positive Age effects (neuropsychological): no difference between twins and controls who were injured between 12 and 36 mo; twins who were injured between 36 and 48 mo had lower scores than their cotwins on four of the performance sub tests; differences were small (< 1 SD) and still within the average range; due to the long injury-to-test intervals (1 - 5 years), we do not know whether the null effect for the younger injuries was due to sparing (i.e., no effect) or recovery Age effects (psychosocial): Twins injured between 12-36 mo had higher scores on an emotional factor; twins injured between 36-48 mo did not differ in ratings of emotionally or temperament
[24]‡ Max et al. (1998b)	*Mild* (*n* = 17): one of the following: LOC < 30 min, PTA ≤ 24h, any alteration in consciousness which does not result in LOC > 30 mins, initial GCS of 13-15 after 30 mins, PTA < 24 hours. *Moderate* (*n* = 12): exceeding mild but less than severe. *Severe* (*n* = 17): LOC > 24h, PTA > 7 days, Lowest post resuscitation GCS ≤ 8 *Age*: mean 6.14 yr	Cross sectional	Consecutive admissions to paediatric clinic	Preinjury psychiatric status taken into consideration	No	T1: mean years between injury and assessment 5.3 yr	Neuropsychological testing: Including WISC-III, WRAT Revised, Schedule for Affective Disorders and Schizophrenia for School-Age Children - epidemiologic version (K-SADS-E).	Adverse findings: Increased rates of ADHD and ODD/CD following MHI. While children developing ODD/CD had more family history of families alcohol dependence/abuse, there was no differences between children with no Hx of ADHD and those who developed ADHD following head injury. Weakness of study is reliance on retrospective assessment of preinjury psychiatric status & outcomes reported for HI group as a whole.

Study	Head injury definition	Design	Source of participants	Preinjury factors	Non head injured control group(s)	Follow-up(s)	Type of assessment	Reported outcome
[25]‡ Max et al. (1997a-c)	Mild (n = 26) lowest post resuscitation GCS score 13-15 irrespective of linear fracture Moderate (n = 9) GCS 9-12 or 13-15 with intercranial lesion or depressed fracture Severe (n = 15) lowest post resuscitation GCS score ≥ 8 *Age*: 6-14 yr	Prospective	Consecutive head injury admissions to 3 regional hospitals	Pre injury psychiatric status taken into consideration. Exclusion: Hx child abuse, previous head injury involving > 1 night hospital admission. CNS disorder and mental retardation	No	T1: 3 mo, 37 subjects returned for assessment, majority being moderate - severe T2: 6 mo T3: 2 yr, 42 subjects returned for assessment	K-SADS-E, supplemented by K-SADS-P sections on ADHD/ODD alcohol and substance abuse and PTSD module, NPRS. Vineland adaptive behaviour scale, measures of psychiatric history and family functioning and SES	Adverse: Novel psychiatric disorders were reported in 17/37 children during first 3 mo followup, 10/42 children at 6 mo, 16/44 at 1 yr and 15/42 at 2 yr. Psychiatric disorders were predicted by injury severity, pre injury family functioning and pre injury lifetime psychiatric Hx. This series of studies suggests that particular children may be vulnerable to the onset of new psychiatric disorders following MHI.
[26]‡ Overweg-Plandsoen et al. (1999)	*Mild* (*n* = 22): LOC less than 20 mins, PTA less than 15-20 min or two of following: headache, nausea and vomiting, decline of consciousness after lucid interval. *Age*: 0-12 yr	Cross-sectional	Accident & Emergency dept reports	No	Yes (orthopaedic control group)	T1: 2 yr	Questionnaire sent to parents containing yes/no questions related to existence of learning, behaviour concentration or physical problems since accident.	Adverse: Main symptoms headache, dizziness, fatigue & memory problems Total number of symptoms in CMH exceeded 4 times this in group of children with a fractured bone. Weakness of the study was that no preinjury characteristics were taken into account. Wide age range. Used multi-choice questionnaires with a high rate of non responders (55%).
[27] Papero et al. (1993)	*Mild* (*n* = 63): GCS 13 with or without evidence of skull fracture or bleeding with no CT evidence of parenchymal damage *Moderate* (*n* = 18k): GCS ≥ 13 with neuroimaging evidence of BD or GCS 9-12 *Severe* (*n* = 5):GCS=3-8	Cross-sectional	Registry of children with a head injury admitted to paediatric medical centre	Exclusion criteria: children with penetrating head wounds and evidence of child abuse	No	T1: 1-3 yr post injury	Neuropsychological: WISCR, Halstead-Reitan battery, VMI, Fuld Object Memory Evaluation (used only to correlate with VABS outcome) Psychosocial: VABS	Null Psychosocial: Results showed a non significantly higher rate of premorbid injuries of all kinds in the mild group and a non significantly higher rate of prior learning difficulties; the effects of injury severity on adaptive functioning was limited to younger boys in the moderate-severe group but not the mild group

Table 1. *(continued)* **Methodological Characteristics of Studies of MHI in Children and Adolescents (1970–2000)**

Study	Head injury definition	Design	Source of participants	Preinjury factors	Non head injured control group(s)	Follow-up(s)	Type of assessment	Reported outcome
[28]‡ Pentland et al, (1998)	*Mild-Mod* (n = 17): not defined Severe (n = 16): not defined Age: 12-16 yr	Cross-sectional	Hospital admissions	Exclusions: Hx of neurological, psychiatric or learning disorders	Yes: non injured volunteers	T1: more than 18 mo post injury	WISC-III, A planning task	Null: No difference in planning skills or WISC-III scores were apparent for adolescents in the mild-mod group when compared with controls. Severe HI were significantly different to the controls. Used less efficient strategies in planning tasks and had significantly lower IQ scores. Results should be viewed with caution as not only were sample sizes for each group small, it is not possible to determine how different severity groups were defined.
[29]‡ Robin et al. (1999)	*Mild* (n = 28): lowest post-resuscitation GCS ≥ 13 *Moderate to severe* (n = 21): *Moderate*: lowest post-resuscitation GCS 9-12 *Severe*: lowest post-resuscitation GCS ≤ 8. *Age*: 6-16 yr	Cross sectional	University hospital admissions	Exclusions: Hx mental retardation, child abuse or HI	Yes (matched for age to orthopaedic injury control group)	T1: minimum of 2 yr post injury	Sustained attention assessed.	Adverse findings: MHI group had deficits in sustained attention demonstrating significant vigilance decrements. Subjects showed progressively declining performance on sustained attention task, not found on orthopaedic controls, referred to as attention fatigue by authors. Severe HI resulted in greater attentional deficits than either MHI or controls.
[30] Thompson et al. (1994)	*Mild-mod* (n = 35): GCS > 8 *Severe* (n = 14): GCS 58	Prospective	Neurosurgery unit in hospitals	Exclusion criteria: Hx of previous brain trauma, penetrating wound to the head, or injury to spinal cord; Hx of neurological handicap or severe behavioural disturbance, antecedent LD, or a failure to regain consciousness within 3 mo of the injury	No	T1: following resolution of post traumatic confusion T2: 6 mo post injury T3: 1 yr post injury T4: 2 yr post injury TS: 3 yr post injury T6: 4 yr post injury T7: 5 yr post injury	Neuropsychological: motor, visuospatial, and somatosensory skills	Indeterminate*

Study	Head injury definition	Design	Source of participants	Preinjury factors	Non head injured control group(s)	Follow-up(s)	Type of assessment	Reported outcome
[31]‡ Wrightson et al. (1995)	*Mild* (*n* = 78): attendance at accident department and having been diagnosed as having had a MHI not sufficient to warrant admission. *Age*: 2.5 - 4.5 yr	Longitudinal	Accident & Emergency dept	Exclusion criteria: Hx of HI	Yes (minor injury control group (*n* = 86), Found no difference between CHI and controls on a variety of preinjury factors)	T1: 1 mo T2: 6 mo T3: 12 mo T4: 2-4 yr at age 6.5 yr	Extensive battery of tests including: VABS, Conners Parent Questionnaire, Neale analysis of reading ability, sub tests of WISC-R, Tests of verbal and visual memory and visual perception.	Adverse: No differences on cognitive tests immediately after injury, but at 6 & 12 mo children scored < controls on visual puzzle. At 6.5 yr more likely to need help with reading. Authors concluded MHI was associated with subtle changes which could impact on school performance. This study used a large sample and an appropriate control group.
Maximum period of follow up after head injury of less than 1 year								
[32] Asarnow et al. (1995)	*Mild* (*n* = 137): uncomplicated injury, not requiring hospitalisation, from blunt forces. and characterised as concussion; AIS score 1, 2, or 3 *Age*: 8-16 yr	Prospective	Emergency rooms	Statistically controlled	Yes (n = 114)	T1: Within 1 mo post injury T2: 6 mo post injury T3: 12 mo post injury	Neuropsychological (extensive battery) Academic Psychosocial: CBCL and AIM	Null: Neuropsychological: After statistically and experimentally controlling for preinjury risk factors, no neuropsychological sequelae specific to MHI was found Psychosocial: No differences among groups on any of the domains of the AIM; results on the CBCL suggested that the parents of the mild group perceived a higher rate of problems in the 6-month period that preceded the accident than did the parents of the other groups, although none of these concerns were of clinical significance
[33]‡ Bassett et al. (1990)	Mild (*n* = 19): GCS 13 - 15 Severe (*n* = 10): GCS 4 -8 *Age*: adolescent, mean 15.7 yr	Cross-sectional	Treated at University trauma centre	No Hx of neurological deficits	Yes (n = 29) selected for similar age, education & SES	T1: within 2mo of injury	WAIS-R or WISC-R, WMS, Logical Memory & Visual Reproduction subtests, immediate & delayed recall, Buschke Selective Reminding Test, WCST, Trail Making Test, Controlled Oral Word Association Test.	Adverse: Mildly injured patients exhibited some dysfunction in verbally based measures of learning, abstraction, and reasoning. Unimpaired on measures of attention, motor speed & visual memory. Study weakened by small sample size.

Table 1. *(continued)* **Methodological Characteristics of Studies of MHI in Children and Adolescents (1970–2000)**

Study	Head injury definition	Design	Source of participants	Preinjury factors	Non head injured control group(s)	Follow-up(s)	Type of assessment	Reported outcome
[34] Bawden et al. (1985)	*Mild* (n = 47): LOC < 20 min (including linear skull fracture) *Moderate* (n = 23): LOC > 20 min, or neurological signs, EEG, or CT abnormality *Severe* (n = 17): GCS 3-7 and required ICP monitoring	Retrospective	Hospital patients who had received medical treatment for a head injury	Exclusion criteria: Previous neurological or behavioural disorders	No	T1: Approximately 1 yr after injury	Neuropsychological: modified Halstead-Reitan battery (including WISC-R)	Null: MS of the mild group were well within the average-to-above-average range on each standardised tests; however, no normal control group was matched to the mildly injured
[35]§ Casey et al. (1986)	*Mild* (n = 321): Hx with no signs of concussion, LOC, skull fractures, no hospital admittance, memory loss, or neurological impairment *Age*: 6 mo - 14 yr	Retrospective	Consecutive admissions to emergency room in hospital	Exclusion criteria: suspected child abuse	No (used questionnaire, with local norms for younger and older children)	T1: emergency room contact made and demographics gathered T2: parent questionnaire administered over the phone	Telephone questionnaire focused on physical, behavioural symptoms (sleep disturbance, moodiness, and discipline problems) and school attendance	Adverse: Results revealed substantial functional morbidity based on a behavioural screening questionnaire (younger group, 13. 1 % vs. 25.0%; older group, 2.7% vs. 27.1%); school absenteeism was also high for the preschool children (29% vs. 10% local preschool rates) and older children (40% vs. 19% local rates); no increase in reports of physical symptoms commonly associated with head injury; they attributed the increase in school absenteeism and behavioural problems to parental overreaction and possible family dysfunction
[36] Ewing-Cobbs et al. (1990)	*Mild* (n = 21): PTA ≤ 7 days *Moderate* (n = 7): PTA 8-14 days *Severe* (n = 9): PTA > 14 days	Prospective	Paediatric neurosurgery service in hospitals	Exclusion criteria: Previous head injury, acquired or congenital insults to the CNS, inadequate school achievement prior to the injury, and ESL	No	Acute: daily at bedside until PTA resolved T1: after resolution of PTA T2: 6 mo T3: 12 mo	Neuropsychological: Verbal and Nonverbal Selective Reminding Test	Adverse (mild): Performance on verbal memory test was interpreted as wit hin normal limits; performance on the nonverbal memory task was reduced at baseline but showed steady improvement and recovery by 12 mo; this interpretation is problematic, given the lack of a non injured control group to determine the status of the initial performance level as well as recovery versus practice effects; classification of children on the basis of a PTA < 7 days may have been comprised of children with more severe injuries

Study	Head injury definition	Design	Source of participants	Preinjury factors	Non head injured control group(s)	Follow-up(s)	Type of assessment	Reported outcome
[37] Ewing-Cobbs, Levin, et al. (1989)	*Mild-mod* ($n = 8$): concussion resulting in LOC < 24 hr and a GCS score ≥ 9, PTA ≤ 7 days *Age*: younger group: 4 months-3.5 yr; older: 3.5-7 yr	Cross-sectional	Paediatric neurosurgery service. in hospitals	Exclusion criteria: previous head injury, other acquired or congenital CNS insults. inadequate premorbid school achievement, and ESL	No	T1: following resolution of PTA T2: 6 mo post injury T3: 1 yr post injury	Neuropsychological: basic intellectual functions, language processing. and motor skills	Adverse: Mild- mod group was reduced on the baseline evaluation, as indicated by the significant increase in scores at 8 mo post injury; Ewing-Cobbs et al. concluded that this differential pattern of change indicated an initial performance deficit and subsequent recovery; this conclusion is problematic, given the lack of a non injured control group to determine the status of the initial level of performance as well as recovery versus practice effects Age effects: The express language disturbance in the mild-mod group was greater in the participant, suggesting that skills in a rapid phase of development may be more susceptible to the effects of brain injury
[38] Ewing-Cobbs et al. (1987)	*Mild* ($n = 23$): normal CT, LOC < 15 min. no neurological deficits *Moderate-severe* ($n = 33$): positive CT, LOC > 15 min	Cross-sectional	Neurosurgery service in hospital	Exclusion criteria: Hx of CNS insult, inadequate premorbid school achievement, evidence of neuropsychiatric disorder, indications of child abuse, lack of recovery to a testable level within 6 mo post injury	No	T1: approximately 1 mo post injury	Neuropsychological: focused on language tests (NCCEA)	Null: Mild group performed well within the average-to-above-average range on the composite language measures Age effect: Children were more impaired on written language than were adolescents; the researchers noted that written language functions may be more vulnerable to brain injury because incomplete stage of development in younger children
[39]§ Fletcher et al. (1990)	*Mild* ($n = 13$): admit GCS 13-15, LOC < 20 min, no skull fractures, mass lesion, swelling, or deterioration after admission *Moderate* ($n = 10$): admission GCS 9-12, or 13 - 15, with skull fractures and mass lesion *Severe* ($n = 22$): initial GCS 3-8 *Age*: 3-15 yr	Prospective	Paediatric neurosurgery service in hospitals	Exclusion criteria: Hx of head injury, acquired or congenital CNS insults, psychological disorder. LD, ADD. MR, or DD	No	T1: when resolution of PTA could be clearly documented T2: 6 mo post injury T3: 12 mo post injury	Neuropsychological: memory (CRMT, selective reminding) language (Word Fluency and PPVT), and perceptual -motor (VMI) Psychosocial: CBCL and VABS Severe: associated with declines in adaptive functioning Mild-mod: did not differ at average levels at follow-up points	Null Psychosocial: No impairment was found in adaptive functioning (VABS) or behavioural functioning (CBCL) at baseline or subsequent, follow-up assessments

Study	Head injury definition	Design	Source of participants	Preinjury factors	Non head injured control group(s)	Follow-up(s)	Type of assessment	Reported outcome
[40]‡ Greenspan et al. (1994)	*Minor* (*n* = 60): GCS 13-15 *Moderate* (*n* = 12): GCS 9-12 *Severe* (*n* = 19): GCS 3-8 *Age*: 5-15 yr	Cross Sectional	Hospital discharge information	Yes	Reference group	T1: 1 yr	Parental phone interview: Behaviour problems index, Rand scale on physical health	Adverse: 55% of the total HI group had difficulties in one or more areas of physical health (role activity, self care, mobility, physical activity). Head aches were the most commonly reported health problem. There was also increased behavioural problems and increased in enrolment in special education group. Children with severe injuries had more problems than mild group but all the HI children showed greater difficulties than a random selection of children the same age A weakness of the study was that information regarding family functioning and pre injury characteristics relied on recollection one year post injury.
[41]§ Gulbrandsen (1984)	*MHI* (*n* = 56 children-adolescents): Dx of concussion (LOC < 15 min or at least two post concussive Symptoms, such as amnesia, nausea, drowsiness, or somnolence) *Age*: 9-13 yr	Retrospective	Neurosurgical service in hospital	Exclusion criteria: more than one head trauma, Premature birth. developmental abnormalities, childhood disease that affected the brain, and psychiatric treatment	Yes (n = 56)	T1: 4-8 mo after being hospitalised for a concussion	Neuropsychological: standardised battery of 32 tests (including Reitan-Indiana and WISC)	Adverse: Test results showed significant differences between HI children and the control group on 29/32 tests, 7 of these were related to concussion; age effects, greater effect of CHI on neuropsychological performance in younger age groups (9 - 10) and (11 - 12), than on the older 13 yr group
[42] Hannay & Levin (1988)	*Mild* (*n* = 33): GCS 13-15, normal CT *Moderate* (*n* = 17): GCS 13-15 with abnormal CT; or GCS 9-12 *Severe* (*n* = 41): GCS ≤ 8	Cross-sectional	Neurosurgery service of hospital	Exclusion criteria: Hx of alcoholism, other neuropsychiatric disorder, or hospitalisation for CHI	Yes (n = 46)	T1: Mild M = 9 days, moderate M = 24 days, severe M = 79 days	Neuropsychological: CRMT	Null: no difference between percentage of outliers in the mild and control groups; no differences between the mild and control group in terms of hits, false alarms, and total correct; it should be noted that the mild group showed no impairment even though they were tested much earlier post injury than the other groups
[43] Jordan et al. (1990)	*Mild* (*n* = 10): GCS > 8 *Severe* (*n* = 10): GCS ≤ 8	Retrospective	Previous admissions to hospital	Exclusion criteria: Hx of head injury. intellectual handicap. acquired or congenital neurological disease or disorder	Yes (n = 20, other injury control group)	T1: at least 12 mo post injury	Neuropsychological: BNT	Null: No differences between mild-mod group and matched controls

Table 1. *(continued)* Methodological Characteristics of Studies of MHI in Children and Adolescents (1970–2000)

Study	Head injury definition	Design	Source of participants	Preinjury factors	Non head injured control group(s)	Follow-up(s)	Type of assessment	Reported outcome
[44]‡ Kaufmann et al. (1993)	*Mild* (*n* = 11): GCS 13 - 15, impaired consciousness of ≤ 15 min, no CT evidence of intercranial lesion, no acute neurological deficit *Moderate* (*n* = 13): GCS 9 - 12 or 13 - 15 with presence of intercranial lesions on CT or acute neurological deficit *Severe* (*n* = 12): GCS ≤ 8 *Age*: 7 - 16 yr	Cross sectional	Consecutive hospital admissions	Exclusions: Preinjury HI resulting in an alteration of consciousness, acquired/congenital central nervous system insult, child abuse/neglect, psychological disturbance, LD, ADHD, mental retardation, other developmental disorders or persistent vegetative state	No	T1: 6 mo post injury	Continuous performance test & WISC-R digit span sub test	Null: While severe HI associated with impairment of attention, performance of mild to moderate groups approximated average score in normal children of similar age. Age effect: younger children with severe HI exhibited more pronounced impairment on continuous performance test relative to uninjured age peers.
[45] Knights et al. (1991)	*Mild* (*n* = 32): GCS 13-15, LOC < 20 min, admitted overnight, linear effects, no LOC *Moderate* (*n* = 18): GCS 8-12, LOC > 20 min abnormal CT, neurological deficit *Severe* (*n* = 20: GCS 7 or less, significant neurological deficits on CT	Prospective	Consecutive admissions to paediatric hospital	Exclusion criteria: Hx of neurological disorder, MR, or serious childhood disease	No	T1: hospital discharge T2: 3 mo after T1 T3: 9 mo after T1	Neuropsychological: WISC-R and modified Halstead-Reitan battery Academic: WRAT-R Psychosocial: Conner's Parental Questionnaire (asked to rate premorbid behaviour as well as current behaviour)	Null Neuropsychological: Tests most sensitive to head injury were those with a speeded motor or psychomotor component; in most of the tests, there was no difference between the mild and moderate groups, and performances were in the average-to-above-average range; a lack of a control group precludes a more direct test of the effects of MHI Academic: Mild group Ms were in the high average range on the WRAT-R . Psychosocial: 29% of parents in the mild group endorsed ≥ one change in behaviour from before the injury to the present time, which is consistent with post concussive symptom base rates in the general population
[46] Leahy et al. (1987)	*Mild* (*n* = 29): z score derived from GCS and length of hospital stay, z ≤ 0 = mild *Severe* (*n* = 13): z score of 1 SD > M *Ages*: 7-13 y	Cross-sectional	Consecutive admissions to paediatric neurosurgery service in hospital	Not considered	Yes (n = 46)	T1: 1 mo post hospital discharge T2: 6 mo post onset T3: 12 mo post onset	Neuropsychological: Token Test, EOWVT, PPVT, Word Fluency, CVLT, test recall, Rey-O Complex Figure, GP, trails, underlining test. VMI, and WISC-R Academic: WRAT-R	Null Neuropsychological: No differences between the mild group and the non injured control group on any of the neuropsychological measures; indeed. the M and percentile scores were almost identical in the mild and control groups, even on speeded psychomotor tasks Academic: WRAT-R M percentiles were almost identical for the mild and control groups

Study	Head injury definition	Design	Source of participants	Preinjury factors	Non head injured control group(s)	Follow-up(s)	Type of assessment	Reported outcome
[47] Levin et al. (1994)	*Mild-mod* (*n* = 49 + 24): GCS > 8 (M GCS for the younger group, 13.4; M GCS for the older group, 12.5) *Severe* (*n* = 24): GCS < 8 (M GCS for both older and younger group, 6.0)	Cross-sectional	Consecutive admissions to neurosurgery service in hospitals	Exclusion criteria: Hx of neuropsychiatric disorders, LDs, previous CHI, mental deficiency, and physical abuse	Yes (n = 89)	T1: minimum post injury interval of 3 mo	Neuropsychological: single cognitive task, TOL	Null: Although the Ms were identical for the mild-mod and control groups, the mild-mod group tended to break the rules more often than the controls (but less often than the severe group); MRI scans showed that the rule-breaking performance was more related to abnormal signal activity in the frontal regions than to injury severity; however, the question of MHI was confounded with moderate injury Age effect: Younger children showed more difficulty with problem solving and maintaining rules, although a ceiling effect may have existed for some of the older patients
[48]§ Levin et al. (1982)	*Mild-mod* (*n* = 30): GCS > 8 *Severe* (*n* = 30): GCS ≤ 8 (15 children and 15 adolescents in each group) *Age*: Mild-mod 5-12 yr Severe 2-12 yr	Cross-sectional	Chart review	Exclusion criteria: Hx of neuropsychological disorder through a review of the school records and detailed developmental Hx	No	T1: after resolution of PTA T2: (only for patients who exhibited problems at baseline) severe: 1-52 mo; mild: 2.0-2.3 mo	Neuropsychological: WISC-R selective reminding test, and CRMT	Null: Results showed a robust dose effect at baseline with more impairment in the severe group than in the mild-mod group; M scores of the mild-mod group were in the average range Age effect: Younger group showed poorer recovery at 12 mo; however. findings could have been confounded by ceiling effects for the older children
[49] Levin & Eisenberg (1979a)	*Grade 1* (*n* = 38): conscious on admittance, only momentary LOC, no neurological deficits; 1/3 of those referred for CT had abnormal findings *Grade 2* (*n* = 7): LOC < 24 hr or neurological deficits *Grade 3* (*n* = 19): LOC > 24 hr *Younger*: (*n* = 22) 6-12 yr old, (*n* = 44) 13-16 yr old	Cross-sectional	Neurosurgical service in hospital	Exclusion criteria: Hx of neuropsychiatric disorder, LD, or inability to cooperate with neuropsychological assessment, plus school records and developmental Hx were reviewed prior to inclusion into the study	No	T1: Most were tested during initial hospitalisation, but some were tested later T2: approximately 1 mo post injury (Mdn = 19 days, range 1-185 days)	Neuropsychological: WISC-R or WAIS-R, aphasia screening. visuospatial and visuomotor abilities, memory (Bushke), and somatosensory perception and motor speed	Adverse: Mild: A small of outliers (which ringed from 12-25%) primarily on tests of language. visuospatial ability, and memory; unfortunately the authors provided no chi square test on these proportions to determine whether there was an effect of mild head injury; use of reference norms provides no information on the expected number of outliers by age category for each test (as well as practice effects); without a normal control group and a follow-up assessment, it is difficult to determine whether an initial effect existed and whether it remitted over time Age effect: No age at injury effect between children and adolescents appeared. although only a few memory tests were given to the children

Study	Head injury definition	Design	Source of participants	Preinjury factors	Non head injured control group(s)	Follow-up(s)	Type of assessment	Reported outcome
[50] Light et al. (1987)	Not defined	Cross-sectional	Outpatient treatment centre	Exclusion criteria: preexisting brain dysfunction (normal cognitive and adaptive functioning prior to injury)	Yes (n = 60 other injury; n = 21 non injured controls)	T1: at least 1 yr after emergence from PTA	Neuropsychological: KABC, category test, EOWVT, Verbal Fluency, Continuous Performances Test. Span of Apprehension, and memory battery	Indeterminate*
[51] Mattson et al. (1990)	*Mild* (*n* = 15): GCS ≥ 13 without focal MRI lesions or evidence of upper extremity injury	Prospective	Hospital admissions	Exclusion criteria: Hx of LD or neuropsychiatric, disorder	Yes (n = 32)	T1: baseline T2: 6 mo post injury T3: 1 yr post injury	Neuropsychological. speeded motor tasks (Trails A and B, GP), verbal memory task (VSR)., nonverbal memory task (CRMT)	Adverse: Some differences between the control and CHI groups at baseline for GP non dominant hand, VSR ($p < .05$), and CRMT ($p < .01$) Age effects: Older mild CHIs had more difficulty on both of the memory tests and the younger mild CHIs had more difficulty on the GP; difference between the mild CHI and the controls, and the older and younger CHIs disappeared at 6 mo and 12 mo (except for CRMT in the older mild CHIs Ages 10-15); however. the M score for the control group was nearly 2 SD > M of the normative sample, and it may not have been an appropriate comparison group
[52]‡ Mittenberg et al. (1997)	*Mild* (*n* = 38): GCS 13-15 , normal CT, no skull fractures *Moderate to severe* (*n* = 27): GCS < 13 or with abnormal CT or skull fracture *Age*: 6 - 15 yr	Cross sectional	Consecutive hospital admissions	Developmental Hx assessed	Yes (orthopaedic injury group)	T1: 6 wk post injury	Structured symptom check list consistent with paediatric post concussion syndrome as defined by ICD-10 and DSM-IV	Adverse: Different from controls on a variety of post concussive symptoms including attentional, headaches, memory difficulties, dizziness and anxiety. 11% of the moderate-severe and 16% of the mild head injury group were asymptomatic compared with 40% of controls. Symptoms were related to HI severity and anxiety level. A weakness of the study was that it relied on the HI child as sole informant.
[53]‡ Ponsford et al. (1999)	*Mild* (*n* = 130): LOC less than 30 min, PTA of less than 24 hours. GCS of 13-15 on presentation at emergency room. *Age*: 6-15 yr	Prospective	Accident & Emergency dept	Found no difference between CHI and controls on a variety of preinjury factors Statistically controlled for a number of preinjury factors	Yes (minor injuries not involving the head with a possible stay of < 24 hr)	T1:1 wk T2: 3 mo	Behavioural assessment: CBCL and Rowe Behavioural Inventory, Post Concussion Syndrome Checklist. Neuropsychological battery: Including sub tests of the WISC-III, PPVT and WRAML.	Null: MHI children showed no cognitive impairment relative to controls at either 1 wk or 3 m post injury. Increased reports of headaches and dizziness evident at 1 week post injury had resolved by 3 months post injury. 17% of children continued to show deficits at 3 mo, Hx of previous injury & premorbid stressors were found to be significantly related to continuing deficits.

Study	Head injury definition	Design	Source of participants	Preinjury factors	Non head injured control group(s)	Follow-up(s)	Type of assessment	Reported outcome
[54]‡ Prior et al. (1994)	*Mild* (*n* = 37): coma > 5 min but < 1 hr *Mod* (*n* = 10): coma 1 hr - 24 hr *Severe* (*n* = 13): coma >24 hr *Age*: 6 - 16 yr	Longitudinal	Consecutive admissions to a children's hospital	No Hx of HI or neurological disorders	No control group, tests with normative data used	T1: as soon as possible, 3-16 wk post injury T2: 6 mo post injury	Neuropsycological tests: Buschke Selective Reminding Test, WISC-R, Austin Maze, WAT-R, Rey Figure & WCS Psychosocial tests: CBCL, TRF, General Health Questionnaire & McMaster Model Family Assessment Device	Null: no deficits detected for children in the MHI group on any of the neuropsychological tests at either follow up time. Children with mod-severe HI showed deficits on measures of reading and spelling and had lower WISC-R scores at both time periods. Family and parental functioning was in the normal range. No consistent indication of behavioural problems in the HI groups.
[55] Slater & Kohr (1989)	*Mild* (*n* = 20): GCS 13-15 *Moderate* (*n* = 3): GCS 9-12 *Severe* (*n* = 11): GCS 3-8	Cross-sectional	Trauma units or paediatric ICU of hospital	Found no difference between CHI and controls on a variety of preinjury factors	Yes (n = 32)	T1: during initial hospitalisation T2: 6 mo post injury (CHI group only)	Neuropsychological: WISC-R or WAIS-R, PPVT, and GORT Academic: WRAT-R	Indeterminate*
[56]§ Tompkins et al. (1990)	Several measures of severity were treated as continuous variables. (*n* = 38) GCS = 15; (*n* = 33) GCS = 9-14; (*n* = 13) GCS ≤ 8. *Age*: 5-16 yr	Prospective	Consecutive hospital admissions	Exclusion criteria: Hx of psychiatric illness; used regression analysis to look at physical, psychological, or cognitive disorders and occupation and marital status of parents	Yes (n = 88)	T1: 1 mo T2: 6 mo T3: 12 mo	Neuropsychological: CVLT, digit span. Ray-O Complex Figure, VMI, trails, GP, underlining tests, PPVT, grammatical comprehension, TOAL, Token Test, EOWVT, Word Fluency. Cookie Theft, Rapid Automatised Naming Test, and story retelling	Indeterminate*
[57] Winogron et al. (1984)	*Mild* (*n* = 17): LOC < 20 min (including linear skull fractures) *Moderate* (*n* = 17): LOC > 20 min, or neurological signs, EEG, or CT abnormality *Severe* (*n* = 17): GCS 3-7 and required ICP monitoring (mild M age: 10.7; moderate M age: 10.4; severe M age: 10.4)	Retrospective	Hospital patients who had received treatment for a head injury	Exclusion criteria: previous head injury, psychiatric treatment, hyperactivity, speech problems with EEG abnormality, or overactivity in combination with behavioural or learning difficulties	No	T1: 0.9- 1. 1 yr post injury	Neuropsychological: WISC-R, PPVT, Category Test, Tactual Performance Test, Tapping Test, Finger Agnosia, GP, Aphasia Screening Battery, Sentence Memory Test, Fluency Test, Target Test, and trails Academic: WRAT	Null: Ms on tests in the mild group were well within the average-to-above-average range and differed significantly from the severe group; however, on two of the tests, approximately 15% of the mild group were impaired; unfortunately, the lack of a control group makes it difficult to determine whether the proportion of participants on these two tests was significantly different from a matched non injury control group

Study	Head injury definition	Design	Source of participants	Preinjury factors	Non head injured control group(s)	Follow-up(s)	Type of assessment	Reported outcome
[58]‡ Yeates et al. (1999)	*Mild* (*n* = 26): LOC < 30 mins, GCS ≥ 13, loss of memory for events surrounding accident, or alteration in mental state at time of accident. *Age*: 8-15 yr	Prospective longitudinal	Accident & Emergency dept	Exclusions include: required surgical intervention or had multiple trauma, Hx of previous HI, neurological disorder, mental retardation or injury a result of abuse and control for preinjury characteristics	Yes (use of siblings)	T1: 7 days after injury T2: 3 mo after injury	Behavioural assessment: CBCL Neuropsychological testing including WISC-III short form, WISC-III digit span & coding sub tests, WCS, CVLT, Trailmaking test & Childrens Paced Serial Addition test	Adverse: 35% of the children showed increases in post concussive symptoms and were more likely to show distractibility, tiredness & difficulty maintaining attention. Those with increased PCS symptoms showed poorer neuropsychological functioning, demonstrated poorer behavioural adjustment, decreased motivation when compared with HI children without PCS. These differences were partially resolved at 3 mo post injury. Small sample size is a weakness along with small control group (only 8 siblings controls were used for the HI group).
[59] Yeates et al. (1995)	*Mild-mod* (*n* = 13): GCS > 8, impaired consciousness < 1 day *Severe* (*n* = 34): GCS = 8 or less, impaired consciousness > 1 day *M* age at injury: 10 yr, 4 mo (SD = 37 mo); M age at testing: 11 yr, 1 mo (SD = 34 mo)	Cross-sectional	Neuropsychology service	Exclusion criteria: Hx of head injury or other neurological disorder, special education or grade retention, DD, or ADHD	Yes (n = 47)	T1: 9 mo (M interval between injury and testing; SD = 11 mo; 70% tested within 1 yr of injury)	Neuropsychological: focused on memory (CVLT) as part of a larger neuropsychological battery	Indeterminate*
No defined period of followup / non specific outcomes								
[60]‡ Leathem & Body (1997)	*Mild-mod* (*n* = 18): mild 5 - 60 min PTA, mod 1 - 24 hr PTA *Age*: 11-14 yr at time of injury	Retrospective	Year 10 school students from a local secondary school (predominantly 14 yr olds)	Not considered	Yes: control group from year 10 students (n = 17)	T1: No uniform followup time, up to 3 yr post injury	Self-report questionnaire: regarding general functioning and symptoms. Neuropsycholgical tests: AVLT, PASAT, Digit symbol subtest from WISC-R, Word Fluency test, Teacher Report Form and Behaviour Checklist (TRF) (adapted from CBCL). An adapted form of the TRF was used with parents	Null: Neropsychological Test: no significant difference between MHI group and controls on any neuropsychological tests, apart from two trials of the AVLT which the head injured group scored lower. Self-report questionnaire: significant difference between HI group and control group on symptom measure but not on measures of general functioning. While there was some indication of deficits in the HI group this finding is weakened small sample size and the reliance on the accuracy of self-report data.

Table 1. *(continued)* Methodological Characteristics of Studies of MHI in Children and Adolescents (1970–2000)

Study	Head injury definition	Design	Source of participants	Preinjury factors	Non head injured control group(s)	Follow-up(s)	Type of assessment	Reported outcome
[61]‡ Max & Dunisch (1997)	*Mild* (*n* = 64) not mod-severe, definite HI consisting of one or more of following: Hx LOC, 24hr admission for observation, evidence of decreased adaptive functioning, skull fracture, seizure or concussion *Mod-Severe* (*n* = 10) abnormal CT scan, depressed skull fracture, LOC > 30 min or requirement of neurosurgery *Age*: mean 5.26 yr	Archival	Chart review of children presenting to an outpatient facility over a 3 yr period	Excluded injuries to head without PCS, Hx of neurological disorders	Yes: Children from same outpatient clinic with no Hx of HI, matched by age, sex, race, social class	No uniform follow time	Axis I & II assessments, use of special education services, IQ scores	Null: 3/59 of the comparisons made between HI and control groups were significant. HI group were significantly different from the controls on developmental communication disorder cluster. Autism and pervasive developmental disorder cluster were more frequent in the control group. It was concluded that children presenting to psychiatric clinics with Hx of HI were indistinguishable from matched controls.
[62]‡ Michaud et al. (1993)	Not defined, has to have suffured a head injury (with medical records available indicating positive LOC or concussion) prior to being enrolled in special education services for bahavioural disorder *Age*: 14/16 less than 5 yr at time of injury	Retrospective	From grades 1-5 of a local elementary school	Exclusion from the study if there was behavioural disability associated with another handicapping categoiries such as learning, hearing, visual or mental disabilities	Yes: children from the same school who were not receiving any special services; matched for age, grade, race, gender, socioeconomic status	No uniform followup time	Parental questionnaire	Adverse: children who suffered a HI prior to age 5 were 8.7 times more likely to be subsequently enrolled in special educatrion service for behavioral disorders and 3.3 time more likely if the injury occurred after 5 yr of age.
[63]‡ Segalowitz & Lawson (1995)	Not defined Age: 0-time of assessment, mean age at injury 8.5 yr	Retrospective	From 3 Urban high school survey and an introductory university class	Not considered	Yes (compared those having a reported CHI with those who did not report a head injury)	No uniform follow time	Self-report questionnaire	Adverse: Wide range of psychological and educational symptoms reported including sleep difficulties, social difficulties, increased left handedness, increased diagnosis of attention deficit, depression and speech and language and reading disorders. These findings be viewed cautiously as they relied on a self report questionnaire and there was a lack of a clear definition for MHI

Study	Head injury definition	Design	Source of participants	Preinjury factors	Non head injured control group(s)	Follow-up(s)	Type of assessment	Reported outcome
[64]§ Segalowitz & Brown (1991)	Not defined *Age*: 1-17 yr	Retrospective	Urban high school survey	Not considered	Yes (compared those having a reported CHI with those who did not report a head injury)	No uniform follow time	Self-report questionnaire	Adverse: participants who reported an MHI also reported an increased rate of speech difficulty (stuttering), left handedness, attention deficit-hyperactivity, and math difficulty; given the lack of any control for preinjury factors, the use of a self report questionnaire, as well as ambiguities regarding case definition, these results should be viewed with caution

Note: **ADD** = attention deficit disorder, **ADHD** = attention deficit- hyperactivity disorder; **AIM** = Attention, Impulsivity, and Memory Questionnaire; **AIS** = Abbreviated Injury Scale; **AVLT** = Auditory Verbal Learning Test; **BD** = brain damage; **BNT** = Boston Naming Test; **CBCL** = Child Behavioural Checklist; **CHI** = closed head injury; **CIQ** = Community Integration Questionnaire; **CNS** = central nervous system; **CT** = computerised tomography; **CRMT** = Continuous Recognition Memory Test; **CVLT** = California Verbal Learning Test; **DD** = developmental disability; **DSM-IV** = Diagnostic & Statistical Manual of Mental Disorders (4th ed.); **Dx** = diagnosis; **EEG** = electroencephalogram; **EOWVT** = Expressive One-Word Vocabulary Test; **ESL** = English as a second language; **FIQ** = full-scale IQ; **GCS** = Glasgow Coma Scale; **GDS** = Gordon Diagnostic System; **GORT** = Grey Oral Reading Test; **GP** = Grooved Pegboard (test); **Hx** = history; **ICD-9/10** = International Classification of Diseases (9/10th ed.); **ICP** = intracranial pressure monitoring; **ICU** = intensive care unit; **KABC** = Kaufman Adaptive Behaviour Scale; **K-SADS-E** = Schedule for Affective Disorders and Schizophrenia for School-Age Children - epidemiologic version; **K-SADS-P** = Schedule for Affective Disorders and Schizophrenia for School-Age Children - child present episode version; **LD** = learning disability; **LOC** = loss of consciousness; **MHI** = mild head injury; **mild-mod** = mild and moderate cases; **mo** month(s); **MOS-SF36** = Medical Outcome Study - Short Form 36; **MR** = mental retardation; **MRI** = magnetic resonance imaging; **NCCEA** = Neurosensory Centre Comprehensive Examination for Aphasia; **NPRS** = Neuropsychiatric Rating Schedule; **PIQ** = performance IQ; **PPVT** = Peabody Picture Vocabulary Test; **PASAT** = The Paced Serial Addition Task; **PTA** = post traumatic amnesia; **SES** = Socioeconomic Status; **T#** = time; **TOAL** = Test of Adolescent Language; **TOL** = Tower of London; **TRF** = Teacher report Form; **VABS** = Vineland Adaptive Behavioural Scales; **VMI** = Beery Visual Motor Integration Test; **VSR** = visual selective reminding; **WAIS-R** = Wechsler Adult Intelligence Scale-Revised; **WCS** = Wisconsin Card Sort; **WISC-R** = Wechsler Intelligence Scale for Children- Revised; **WISC-III** = Wechsler Intelligence Scale for Children- version III; **wk** = week(s); **WPPSI** = Wechsler Preschool and Primary Scale of Intelligence; **WRAML** = Wide Range Assesment of Memory And Learning; **WRAT-R** = Wide Range Achievement Test-Revised; **yr** = year(s).

* Studies with indeterminate outcomes did not contain, nor were they typically designed to have, a specific contrast between MHI and a matched non injured group, a contrast between a mild and more severely injured group (moderate or severe) or both on, standardised tests. Many of the studies in the indeterminate category addressed objectives such as dose effects, age-at-injury effects, quality of life issues or injury and demographic factors related to neuropsychological outcome.

(Adapted from Satz et al. 1997)

§ Studies included in the Satz et al. 1997 review but modified or added to in this table: ($n = 13$).

‡ Additional studies reviewed in this table: ($n = 23$).