Journal of the International Neuropsychological Society (1997), **3**, 592–597.

Effect of mild head injury during the preschool years

DOROTHY GRONWALL, PHILIP WRIGHTSON, AND VALERIE McGINN
Concussion Clinic, Auckland Hospital, Auckland, New Zealand

Abstract

This article examines the evidence that the effect of head injury on young children may differ from that in adults, in that while in the latter the pattern is of deficits that recover with time since the accident, this is not necessarily the case with very young children. In this group, there may be no evidence of any deficit in the early days or weeks after injury, but the children may fail to develop some skills as quickly as children who have not had a head injury. Results from a series of studies of MHI in preschool children carried out over a more than 10-year period from Auckland Hospital and recently published studies of pediatric MHI from other groups are reviewed. It is concluded from a comparison of these data that there is a need for long-term prospective studies designed within a developmental framework to clarify the issue. (*JINS*, 1997, *3*, 592–597.)

Keywords: Mild head injury, Children, Cognitive development

INTRODUCTION

Although there is now a compelling body of evidence that mild head injury in adults (MHI) results in cognitive deficits, including memory and concentration problems and slowed information processing (Levin et al., 1989), there is less agreement about the effects of MHI in children. Beers (1992) reviews the literature to that date, including the influential studies by Rutter and his colleagues (e.g., Rutter et al., 1980). The Rutter group considered that though severe head injury (SHI) had significant effects on cognition and behavior, this was not the case with MHI, and that these children had been less capable even before the injuries. However Beers points out several problems with the design of these studies, including inadequate control groups and noncomparability of testing procedures for the different severity-of-injury children. Beers concludes that "although the effects seen after MHI are neither as common nor disabling as those associated with severe injury, they are important to address because the *incidence* of MHI is so much greater" (p. 314). It is rather unfortunate that, in spite of the problems with the studies from Rutter's group, two of the premises that he adopted have persisted. The first is that a deficit can be attributed to the head injury only if it shows successive improvement over time. The second is that there must be a dose–response relationship, with severe head injury (SHI) showing more impairment than MHI.

Apart from the issue of severity of injury, there is no consistent information about the effect of age at injury. It used to be considered that the younger the age at which brain damage of any etiology occurred, the better the outcome (the so-called Kennard Principle), but more recent evidence does not support this view (see Anderson et al., this issue) for a fuller discussion. However, given that the tremendous amount of learning that needs to take place in the first 5 or 6 years of life, and that MHI in adults can affect the ability to acquire new information (Levin et al., 1989), more disruption in younger children could be predicted. Unfortunately there are only a limited number of studies that include the preschool child, no doubt because of the practical problems in assessing either head-injury severity or cognitive ability in very small children.

Table 1 summarizes results from five groups who have included a range of ages in studies of pediatric MHI. Two of the studies are published in this issue (Anderson et al., 1992; Ewing-Cobbs et al., 1997). This paper outlines the other three studies and examines some factors that might account for the differences between their results and those from a series of studies from Auckland Hospital.

Unfortunately, Bijur et al.'s important longitudinal prospective study (1990) is not considered in the Beers review. Bijur examined a subsample of a cohort of some 13,000 British children whose parents reported that they had had

Reprint requests to: Dorothy Gronwall, 3/2 Cotton Street, St. Johns, Auckland 6, New Zealand.

https://doi.org/10.1017/S1355617797005924 Published online by Cambridge University Press

Table 1. Comparison of a sample set of studies of pediatric MHI

Study	Age at injury	Injury–test interval	Effects on cognition	Effects on behavior	Effect of age
Bijur et al. (1990)	0–10 years	1–5 years	No	No	
		5–10 years	?	No	?
Fay et al. (1993)	6–15 years	3 weeks	No	No	N/A*
		12 months	?	No	N/A*
		3 years	?No	No	N/A*
Asarnow et al. (1995)	8–16 years	6 months	No	No	N/A*
		12 months	No	No	N/A*
Anderson et al. (1997)	2–7 years	0–3 months	No	No	
		12 months	No	No	Yes
Ewing-Cobbs et al. (1997)	0–7 years	6 months	No	No	
		12 months	No	No	No
		2 years	No	No	

*N/A = not assessed.

an accident needing medical advice between the ages of 5 and 10 years. Data on behavior and cognitive function were collected, and at age 10 years the battery included measures of reading, mathematical ability, and vocabulary. Although Bijur et al. appear to support Rutter's view that pediatric MHI has no significant effect on cognitive functions, this interpretation depends on acceptance of Rutter's first dictum. When the children were tested at the age of 10, there was a significant difference between the children on the mathematics test depending on age at injury. However, because those injured when they were age 5 or 6 were more impaired than those with the most recent injuries, this was not taken as evidence of an association with MHI.

Two other groups have recently published data that either failed to find, or failed to identify, a significant effect of MHI, though they meet the methodological problems that confounded the earlier studies. The UCLA study is a well-controlled prospective study of children aged from 8 to 16 years examined 1, 6, and 12 months postinjury (Asarnow et al., 1995). The children were from a consecutive series of cases who met clearly defined criteria based on transient symptoms, duration of coma, or amnesia. Two control groups were tested, one of uninjured children matched for sex and age, and the other children from the same hospital who had injuries other than to the head. A range of memory, attention, and executive function measures were recorded, plus data on behavior. The authors found no clinically significant neuropsychological impairments at any test session postinjury. No comparison of the effect of age at injury is made.

The third group (Fay et al., 1993, 1994; Jaffe et al., 1995) tested children age 6 to 15 years at intervals up to 3 years after injury. Severity of injury was defined by GCS in the emergency department. Cases with GCS scores between 13 and 15 at that stage, and who achieved a score of 15 within 3 days of injury, were classed as MHI. Again, a considerable number of tests were used, as well as measures of behavior. Each case was individually matched with a noninjured child on the basis of age, sex, school grade, and premorbid behavior. They concluded that there was no significant effect of MHI on cognition or behavior because only the Coding score was significantly different in the two groups, and then only at the 12-month follow-up. That is, the MHI children did not show an initial deficit that recovered over time, but did show a deficit that only *emerged* over time. Data on the effect of age at injury are not given.

To summarize these studies, evidence that pediatric MHI affects cognition or behavior is at best equivocal. However where comparisons are available, it seems that children in the zero-to-six age-group may be more at risk after head injury than older children. The next section reviews a research project started at Auckland Hospital more than 10 years ago that has consistently found deficits after MHI. In the final section, some possible reasons for the disparate results are examined.

THE AUCKLAND STUDIES

An ongoing research program was begun at Auckland in response to reports from parents and teachers that children with problems learning to read were often found to have had a head injury at some stage before starting school. The investigation has been focused on children with mild injuries, consistent with the theoretical approach of this team. It had seemed logical to predict that, since we had found significant deficits in information processing and memory after MHI in adults, preschool children would be even more impaired, since the period from birth to age 5 years is a time when considerable learning and development occurs. Because of the difficulty of measuring the duration of posttraumatic amnesia (PTA) in this group, MHI was defined as an injury to the head sufficiently severe for the child to be taken to the Emergency Department, and for the staff to initiate 4 to 6 hr of observation, but not severe enough to war-

https://doi.org/10.1017/S1355617797005924 Published online by Cambridge University Press

rant admission to hospital. The issue of definitions of severity is considered further below.

The first pilot study (Dawe, 1982) used all the subtests from the Illinois Test of Psycholinguistic Abilities (ITPA) to examine language development. Children age 2.5 to 4.5 years who met the criteria for MHI given above, who lived in the Auckland area, who had had no previous head injury, and whose first language was English, were matched for age, birth order, socioeconomic status, and parent's education level with children who had not received any injury. Children in both groups were tested three times in their own homes at 4-month intervals. The unusual aspect of the results was that there were no significant differences between the groups at the first test, done within 48 hr of injury, but both 4 and 8 months later the head-injured children were significantly poorer than the control children on both the Visual Memory and the Visual Closure subtests, but there were no significant differences on the other eight ITPA subtests. One of the MHI children was an identical twin, and her sister was her control. The parents were contacted when the children had reached the age of 6 years and asked how they were doing at school. In contrast to her sister, the MHI twin had needed extra help to learn to read.

The second (retrospective) study followed from this. Parents of preschool children who had presented at the Auckland Hospital Emergency Department in the previous 2 to 3 years were contacted to ask for permission to interview them about their child's progress at school. Significantly more children who had had a head injury before they started school were reported by the parent to have had problems learning to read than did children who had had an injury to other parts of the body. This was even though many parents of head-injured children had forgotten the incident, and ascribed their child's problems to other factors such as marital upsets or change of teacher.

These studies led to the design of a long-term prospective study aimed at forming a cohort of all 2.5- to 4.5-year-old children who presented at the emergency department after injuries that were not sufficiently severe to warrant admission to hospital (Wrightson et al., 1995). Two groups of children were formed: those presenting with head injuries, and those with injuries to other parts of the body. All met the inclusion criteria of no previous head injury, and had English as their first language. Both the MHI and accident control children were tested within 1 month of injury, then 6 and 12 months later, with two sessions needed for each assessment. At the first interview, family and socioeconomic status and developmental history were recorded. The Reynell Developmental Language Scale, the ITPA, the Vineland Social Maturity Scale, and the Connors Parent Questionnaire were given at each test interval. A final follow-up, using an expanded battery including reading, memory, and perceptual tests and the WISC Coding subtest, was made when each child reached the age of 6.5 years.

The results were generally similar to those from the earlier pilot study. Soon after injury there was no evidence of any significant difference between the groups on any demographic measure, on parent's ratings of the child's behavior, or on any of the cognitive measures. There was thus evidence both that the groups were well matched, and also that the MHI children were unlikely to represent a different population, as Asarnow et al. (1995) had suggested. However 6 months later the MHI group were significantly worse than the accident controls on the ITPA Visual Closure subtest, but not on any other ITPA subtest or on any of the Reynell scales. This difference was even greater 12 months after the injury, and the deficit in Visual Closure was still found at the 6.5-year test. There was no difference on any of the behavior measures or on social development at any stage. Table 2 summarizes the Visual Closure results from the two studies.

Importantly, significantly more MHI children had needed special help with reading than children who had had a non-head-injury accident before they started school. Children were classed as having reading problems if they had been included in the Clay Reading Recovery Programme at school at the age of 6 years. Further, there was a significant correlation in the MHI group between the Neale reading score (Neale, 1966) when the children were age 6.5 years, and the Visual Closure score 12 months after injury. This rela-

Table 2. ITPA Visual Closure scores from (a) the pilot study and (b) the main Auckland study

	(a) Pilot study (scaled scores)				(b) Main study (raw scores)			
Group/Test	48 hr	4 months	8 months		<1 month	6 months	12 months	6.5 years
Head injury, $N = 9$ Age range 28–49 months Mean age 37 months	37.3	40.7*	43.3**	$N = 78$ Age range 28–52 months Mean age 40 months	4.79	5.47**	6.6**	22.44*
Control, $N = 9$ Age range 28–50 months Mean age 38 months	41.3	48.5	58.8	$N = 79$ Age range 29–51 months Mean age 39 months	5.11	7.00	8.42	25.7

*$p < .05$.
**$p < .01$.

https://doi.org/10.1017/S1355617797005924 Published online by Cambridge University Press

tion was not found in the control group. The pilot study had also found a difference on the ITPA Visual Sequential Memory subtest. The main study did not find an overall group difference, but MHI girls were significantly worse than control girls on this measure. Again this difference developed over time.

Thus, the overall pattern of results from the Auckland studies suggests that MHI in the preschool years does not affect already established skills, so that no group differences are found in the first few weeks after the injury, even in a study such as this, where the comparison is with a very appropriate control group of children who have also had minor accidents. However, it seems that the MHI children did not develop whatever skills are needed to complete the ITPA visual puzzle as rapidly as the other children, and performance on this test 12 months after the injury was a good predictor of reading performance when the child had had approximately 12 months at school.

Asarnow et al. (1995) identify three factors that might account for conflicting results in the children's MHI literature: (1) Sample selection; (2) how MHI is defined; and (3) whether, and how, preinjury factors are controlled for. These are clearly important, but we consider that there are three other, equally important, factors. These six factors are discussed below.

FACTORS AFFECTING RESULTS OF STUDIES OF MHI IN CHILDREN

Sample Selection

There can be no argument that children who are included in a study because they have been referred to a rehabilitation facility for follow-up will have been preselected for the presence of postinjury problems. However all except one of the studies reviewed in this paper, including the main Auckland study, studied children who were consecutive presentations at a hospital emergency department, with the only selection apart from age, residential, and language criteria, being that they had not had a previous head injury or neurological disorder. The exception was the UCLA study, which did not exclude children with previous injuries. This was to increase the generalizability of their data to the population of MHI children, based on their premise that these children have a higher incidence of preinjury problems. However, as noted below, it is not always the case that MHI children are from a different population.

How MHI is Defined

The problem of an acceptable definition of MHI is not restricted to children. There is no generally accepted set of criteria for adults (Kibby et al., 1996), and the measures that have been taken on admission to hospital are not necessarily relevant after MHI. For example, these cases are not comatose when they reach the Emergency Department, so the Glasgow Coma Score (GCS; Teasdale & Jennett, 1974) becomes a very insensitive measure which can include those whose duration of PTA varies from only minutes to several days. Further, there is evidence that PTA duration is not related to return to work after MHI (Wrightson & Gronwall, 1981) and also that it cannot be reliably assessed (Gronwall & Wrightson, 1980). Asarnow et al. (1995) note that PTA assessment in children is even more problematical, even though the children in their study were all more than 8 years old. The children in the Auckland studies were very much younger, so PTA assessment was even less appropriate. Nor was it considered adequate to use loss of consciousness as the criterion, since it has been shown that the incidence is much lower in small children than in adults (Jamison & Kaye, 1974).

For this reason, an operational definition was used in our study. Those children who were discharged home to the care of their parents after 4 to 6 hr of monitoring head injury signs at 15-min intervals by emergency department staff were classified as MHI, in contrast to those admitted to hospital. It is interesting that number of days in hospital is also used as a definition of MHI by investigators of adult MHI (Rimel et al., 1981). It is important to stress, however, that coma depth and duration and other factors were used to define severity of injury in the other studies presented here. No two studies used identical criteria, and it is obviously unrealistic to expect consistent results until consistent definitions are used for pediatric MHI. Perhaps definitions may need to wait for further refinements in technology. In the interim, it is perhaps relevant that a recent study reported an incidence of 9% abnormal MRI scans in adults with persistent problems after MHI, while 53% of SPECT scans were abnormal in the same group (Kant et al., 1997).

Preinjury Factors

There is still conflicting evidence as to whether MHI children are already problem children, with behavior and learning disorders that predate the injury, as the Rutter group concluded. This evidence is reviewed by Beers (1992). The protocol for the UCLA study includes a comprehensive history-taking of preinjury behavioral and medical problems, and level of achievement at school. Their MHI children are reported to have had significantly more behavior problems than the noninjury children (Asarnow, 1995). In contrast, Fay et al. (1993) found no such differences, either in preinjury behavior, or in school performance. Neither were differences in preinjury behavior found in the main Auckland study, though there were differences in the incidence of previous head injuries. However, although more of the initial cohort of MHI children than other injury children had to be excluded because of previous head injuries, and although significantly more MHI than control children were found to have had another head injury at the 6-month follow-up, this apparent susceptibility to further head injury did not persist, and 12 months after the initial injury, the number of accidents in the two groups did not differ (Wrightson et al., 1995). Given the comparability of the groups on pre-injury factors, and the limited time during which it is present, it is probable that the sensitive period reflects transient post-head-injury problems with attention and coordination, which would be likely to put these children more at risk for a further injury, rather than reflecting permanent accident-prone personalities.

Age at Injury

In spite of accumulating evidence that the "Kennard Principle" is untenable, and that brain damage does not have less effect on children than on adults, Johnson (1992) notes that professional as well as lay people still consider that children do better than adults after equivalent injuries. In a recent article, Webb et al. (1996) reported that groups of health care professionals asked to estimate expected recovery in pairs of fictitious cases that differed only in the age of the accident victim all predicted better recovery in younger than in older children. However, with actual rather than hypothetical patients, as Anderson et al. (1997) have noted, several studies have shown that head injury has more effect at earlier ages. They review evidence that children who sustain early injuries have poorer outcomes than those whose injuries occurred later in childhood, and discuss factors that may account for the extra vulnerability of younger children. Consistent with this, the research they report finds that in their group of children injured between the ages of 2 and 7 years, age at injury and injury severity are significant predictors of outcome.

In contrast, Ewing-Cobbs et al. (1997), with a similarly aged sample of children (age range 0–7 years at injury) who were followed up for 2 years, found no significant effect of age on test scores. The difference between the two reports may be that, while Anderson et al. used multiple regression analyses to examine predictors, Ewing-Cobbs et al. used a median split, comparing children from birth to 41 months at injury with those age 42 to 71 months.

Follow-up Interval

In adults, the majority of MHI cases have made a full functional recovery 1, or at most, 3 months after the injury (Levin et al., 1989) though between 5 and 10% can continue to have problems months or years later. Thus, delaying the first assessment until 1 month after the injury reduces the probability of finding significant MHI *versus* control *group* differences in adults. Since adolescents up to the age of 16 were included in the UCLA study, and the mean age of the group was 12 years, recovery patterns similar to those seen in adults would be predicted and, given that the first test was not done until 1 month after injury, the trend towards nonsignificance on memory and information processing tasks would be expected. Children in the Fay et al. studies were younger (*M* age = 9.4 years), but they ranged up to 15 years, and were not tested for a mean of more than 3 weeks after injury. Again this makes it less likely that they would find the type of impairment seen after adult MHI.

A further confounding factor of injury-to-test interval is the assumption, first stated in the Rutter studies, that where a deficit does not improve with time since injury, it cannot have been an effect of the injury. This is also explicit in Asarnow et al.'s (1995) statement that "impairments in the head-injury group should be most apparent . . . 1 month post-injury, because the normal course of CHI . . . is towards recovery of function" (pp. 136–137). As already noted, this has resulted in the dismissal of some significant results. For example, Fay et al. (1993) report that the MHI children were significantly poorer than the controls on the WISC–R Coding subtest a year after the injury, though there had been a nonsignificant difference at the first test. Bijur et al. (1990) found a significant linear correlation between age at injury and arithmetic scores, so that children who had an MHI at age 5 did worse than children whose injury occurred closer in time to the test at age 10 years. Both authors dismiss the possibility that this is the result of the MHI. However both results are similar to those of Wrightson et al. (1995) and raise the possibility that the head injuries occurred at a time where they have interrupted the normal course of development of a skill, so that the MHI group begin to lag more and more behind their controls.

Test Battery and Data Analysis

Children are not miniature adults, and just as clinical signs of head injury differ in small children (Jamison & Kaye, 1974) it is evident from these studies that MHI may affect children's cognitive skills differently from adults. Thus batteries of tasks that sample developmentally sensitive areas could be the most appropriate to use, and investigation of the effects of MHI in young children should be designed within a developmental model.

However, data analysis is a problem with all studies that use multiple comparisons. Polissar et al. (1994) analyzed the Fay et al. (1993) data using three different methods apart from the Bonferroni correction used in the initial papers. They concluded that Bonferroni was too conservative when an injury affects several areas weakly, rather than one single area substantially. However the alternatives are less powerful in detecting one single area of deficit, which may be present in only a restricted proportion of the group. Yet this is exactly the situation with persistent cognitive deficits after adult MHI, where only 5 to 10% of the group may show deficits on formal tests.

The simplest way to avoid the problem of multiple comparisons is to design studies that have only one or two dependent variables. Unfortunately this could lead to time-consuming and expensive exercises unless specific predictions are made within a rigorous theoretical framework. Further, it does not address the issue of significant effects that might occur in only a small proportion of the group.

https://doi.org/10.1017/S1355617797005924 Published online by Cambridge University Press

SUMMARY AND CONCLUSIONS

Although there are no similar reports of impairment after MHI in preschool children, the Auckland studies are not inconsistent with the literature on pediatric head injury. It appears that if the injury occurs at an important developmental age the children may fail to develop a skill or skills as quickly as non-head-injured children. In Wrightson et al. (1995), the deficit 12 months after the preschool injury in the MHI group was significantly related to reading ability at age 6.5 years.

This has important practical implications, since even in Auckland, a city of only 1,000,000 residents, more than 900 preschool children each year are treated at emergency departments but not admitted to hospital after head injury accidents (Wrightson, 1989). Pending confirmation of our results by other workers, it would be sensible for primary school teachers to monitor the reading skills of infants who have had head injuries.

There is an urgent need for well-controlled prospective studies designed within a developmental model, and with long-term follow-up to chart the achievement of MHI children relative to non-head-injury controls. Such studies need to be long-term. One year may be adequate for adolescent head-injuries, but to chart the long term effect of MHI in infancy on development and maturation, a 10- or 15-year follow-up is needed. This would help to answer the questions raised by educators and others involved with problem children, whether MHI-related frontal impairment might predict antisocial behavior some years later (Johnson, 1992).

ACKNOWLEDGMENT

The research on which this paper was based was funded by the New Zealand Neurological Foundation (Grants 84.1 and 88.1 to Philip Wrightson and Dorothy Gronwall).

REFERENCES

Anderson, V.A., Morse, S.A., Klug, G., Catroppa, C., Haritou, F., Rosenfeld, J., & Pentland, L. (1997). Predicting recovery from head injury in preschool children: A prospective analysis. *Journal of the International Neuropsychological Society* (this issue).

Asarnow, R.F., Satz, P.,Light, K., Lewis R., & McLeary, C. (1995). The UCLA study of mild head injury in children and adolescents. In S.H. Bronan & M.E. Michel (Eds.), *Traumatic head injury in children* (pp. 117–145). New York: Oxford University Press.

Beers, S.R. (1992). Cognitive effects of mild head injury in children and adolescents. *Neuropsychology Review*, *3*, 281–320.

Bijur, P, Haslum, M., & Golding, J. (1990). Cognitive and behavioral sequelae of mild head injury in children. *Pediatrics*, *86*, 337–344.

Dawe, S.L. (1982). *Closed head injury in pre-school children*. Unpublished master's thesis. University of Auckland, Auckland, New Zealand.

Ewing-Cobbs, L., Fletcher, J.M., Levin, H.S., Francis, D.J., Davidson, K., & Miner, M.E. (1997). Outcome in young children with TBI. Longitudinal outcome in infants and preschoolers. *Journal of the International Neuropsychological Society* (this issue).

Ewing-Cobbs, L., Levin, H.S., Eisenberg, H.M., & Fletcher, J. (1987). Language function following closed head injury in children and adolescents. *Journal of Clinical and Experimental Neuropsychology*, *9*, 575–592.

Fay, G.C., Jaffe, K.M., Polissar, N.L., Liao, S., Martin, K.M., Shurtleff, H.A., Rivara, J.B., & Winn, H.R. (1993). Mild pediatric traumatic brain injury: A cohort study. *Archives of Physical Medicine and Rehabilitation*, *74*, 895–901.

Fay, G.C., Jaffe, K.M., Polissar, N.L. Liao, S., Rivara, J., & Martin, K.M. (1994). Outcome of pediatric traumatic brain injury at three years: A cohort study. *Archives of Physical Medicine and Rehabilitation*, *75*, 733–741.

Gronwall, D. & Wrightson, P. (1980). Duration of post-traumatic amnesia after mild head injury. *Journal of Clinical Neuropsychology*, *2*, 51–60.

Jaffe, K.M., Polissar, N.L., Fay, G.C., & Liao, S. (1995). Recovery trends over three years following pediatric traumatic brain injury. *Archives of Physical Medicine and Rehabilitation*, *76*, 17–26.

Jamison, D.L. & Kaye, H.H. (1974). Accidental head injury in childhood. *Archives of Diseases of Children*, *49*, 376–381.

Johnson, D.A. (1992). Head injured children and education: A need for greater delineation and understanding. *British Journal of Educational Psychology*, *62*, 404–409.

Kant, R., Smith-Zeemiller, L., Isaac, G., & Duffy, J. (1997). Tc-HMPAO SPECT in persistent post-concussion syndrome after mild head injury: Comparison with MRI/CT. *Brain Injury*, *11*, 115–124.

Kibby, M.Y. & Long, C.J. (1996). Minor head injury: Attempts at clarifying the confusion. *Brain Injury*, *10*, 159–186.

Levin, H.S., Eisenberg, H.M., & Benton, A.L. (Eds.). (1989). *Mild head injury*. New York: Oxford University Press.

Neale, M.D. (1966). *Neale analysis of reading ability* (2nd ed.). London: Macmillan Education.

Polissar, N.L., Fay, G.C., Jaffe, K.M., Liao, S., Martin, K.M., Shurtleff, H.A., Rivara, J.B., & Winn, H.R. (1994). Mild pediatric traumatic brain injury: Adjusting significance levels for multiple comparisons. *Brain Injury*, *8*, 249–264.

Rimel, R.W., Giordani, B., Barth, J.T., Boll, T.J., & Jane, J.A. (1981). Disability caused by minor head injury. *Neurosurgery*, *9*, 221–228.

Rutter, M., Chadwick, O., Shaffer, D., & Brown, G. (1980). A prospective study of children with head injuries: I. Design and methods. *Psychological Medicine*, *10*, 633–645.

Teasdale, G. & Jennett, B. (1974). Assessment of coma and impaired consciousness. *Lancet*, *2*(*872*), 81–84.

Webb, C., Rose, F.D., Johnson, D.A., & Attree, E.A. (1996). Age and recovery from brain injury: Clinical opinions and experimental evidence. *Brain Injury*, *10*, 303–310.

Wrightson, P. (1989). *An eight week sample of head injuries occurring in April–May, 1986 in Auckland*. (Survey commissioned by Accident Compensation Corporation). Auckland, New Zealand: Author.

Wrightson, P. & Gronwall, D. (1981). Time off work and symptoms after minor head injury. *Injury*, *12*, 445–454.

Wrightson, P., McGinn, V., & Gronwall, D. (1995). Mild head injury in preschool children: Evidence that it can be associated with a persistent cognitive deficit. *Journal of Neurology, Neurosurgery, and Psychiatry*, *59*, 375–380.