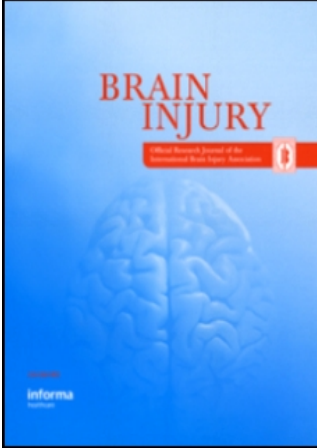


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REVIEW

Behavioural interventions for children and adults with behaviour disorders after TBI: A systematic review of the evidence

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Abstract

Objective: To systematically review the evidence for the effectiveness of behavioural interventions for children and adults with behaviour disorders after TBI.

Design: Using a variety of search procedures, 65 studies were identified. This literature was reviewed using a set of questions about participants, interventions, outcomes and research methods.

Participants: The 65 studies included 172 experimental participants, including children and adults.

Interventions: A number of specific intervention procedures were used, falling into three general categories: traditional contingency management, positive behaviour interventions and supports and combined.

Results: All of the studies reported improvements in behavioural functioning.

Conclusions: Behavioural intervention, not otherwise specified, can be considered a treatment guideline for children and adults with behaviour disorders after TBI. Both traditional contingency management procedures and positive behaviour support procedures can be said to be evidence-based treatment options. However, a variety of methodological concerns block stronger conclusions.

Keywords: Behaviour disorders, rehabilitation, intervention traumatic brain injury, applied behaviour analysis, positive behaviour supports, functional behaviour assessment

Introduction

The purpose of this article is to systematically examine the literature on the effectiveness of behavioural interventions for individuals with behaviour problems after traumatic brain injury (TBI) with the goal of deriving possible treatment guidelines. Aetiologies other than TBI were included in the review only if the impairments and associated disabilities resembled those that are common after TBI and the individual was included in a study that focused on TBI. Pharmacologic studies were omitted from the review. Furthermore, pharmacologic interventions that may have complemented the

behavioural interventions in the current review are not separately analysed because insufficient information was provided in the publications.

Behavioural outcome following traumatic brain injury

Outcome research has shown convincingly that social and behavioural disorders after TBI are common and troubling for the person with TBI, family members, friends, teachers, work supervisors, peers and others. Lists of frequently identified problems include disinhibition, irritability, aggression, sexual acting out, reduced anger control, immature behaviour (relative to age expectations),

rigidity, social awkwardness, impaired social perception, egocentrism, depression and social withdrawal. Estimates of new persisting behavioural disorders (i.e. those not predating the injury) among *children* with severe TBI range from ~35% [1] to 70% [2] with all studies suggesting that a large percentage of this population experiences new persisting behaviour problems after the injury. Furthermore, in children injured in the early or middle childhood years, the persisting behavioural and psychosocial problems negatively influence quality of adult life far more than intellectual or physical problems [3, 4].

Among adults, behavioural disturbances and poor psychosocial adjustment are also common, even in the presence of generally good neuropsychological recovery [5–13]. Baguley et al. [14] found that aggressive behaviour was present in ~25% of adults with TBI at 6, 24 and 60 months post-injury. Aggression was consistently linked to depression, concurrent traumatic complaints, younger age and generally low satisfaction with life, but relatively unrelated to features of the injury, demographics or pre-injury characteristics. Winkler et al. [15] identified loss of emotional control (LEC, including impulsiveness, aggression, irritability and frequent mood changes) as a critical predictor of poor community integration on average 8.8 years post-injury. LEC and level of disability together classified 75% of the participants correctly in high vs low community integration outcome categories.

Among individuals with *mild* TBI, general irritability has been found to persist up to 1 year post-injury in roughly one third of cases [16, 17] and was the most frequently cited symptom of the injury. In the case of *severe* TBI, Brooks et al. [18] identified 64% with irritability at 5 years post-injury. Tateno et al. [11] found that 33.7% of their cohort of 89 patients with mild, moderate or severe TBI had aggressive behaviour after the injury, with no significant difference between the aggressive and non-aggressive groups in severity of injury. The intervention papers included in this evidence review would suggest that both children and adults tend to exhibit relatively more externalizing behaviours (e.g. aggression, hyperactivity, sexual acting out) than internalizing behaviours (e.g. withdrawal). However, in a sample of 100 adults on average more than 7 years post-TBI, Hibbard et al. [19] found that 61% met criteria for major depression at some point post-injury. Furthermore, Geraldina et al. [20] found that very young children (injured between birth and age 6 years) presented with relatively more internalizing symptoms, with the prevalence of externalizing behaviours increasing with age at injury. This finding may be an artifact of lowered expectations for self-regulation in young children, resulting in under-reporting of irritability,

hyperactivity and aggression in the youngest age group.

Irritability, aggression and other externalizing symptoms have been associated with brain systems vulnerable in closed head injury: orbito-frontal cortex, anterior temporal lobe cortex, limbic structures (especially the amygdala) and their interconnections [11, 21–23]. In particular, when frontal control mechanisms are unavailable to regulate limbic impulses, minor everyday provocation can cause aggressive or otherwise socially unacceptable responses [24]. Irritability leading to aggression may be a direct consequence of these pathophysiological changes, an exacerbation of pre-traumatic aggression, poor self-monitoring, an underlying mood disorder, overly restrictive treatments or any combination of these [25].

More generally, a large body of literature supports the critical role of the frontal lobes in social cognition and social behaviour [26–28]. The results of these studies support the contribution of the frontal lobes to social behaviour, but there is debate regarding the exact nature of this relationship. In a review of the literature, Blair and Cipolotti [29] identified five different accounts of aberrant social behaviour after frontal lobe injury, including a lack of access to social scripts [30] and impairments in Theory of Mind [31]. The effects of frontal lobe dysfunction are most apparent on tasks that require integration of context information to generate a response [32], such as inference tasks. The results of functional neuroimaging studies indicate that frontal structures are particularly engaged by tasks that require processing of social information (possibly right hemisphere more than left) and that this activation is significantly reduced in individuals with pragmatic communication disorders [31, 33]. These impairments have been linked to poor social outcomes after TBI [34, 35].

Laterality effects in relation to social outcome remains controversial. Some studies have reported laterality effects on specific social cognition tasks [36–38]. By contrast, using a global measure of social outcome (scores on the Vineland Adaptive Behaviour Scales), Levin et al. [39] found no significant difference in social outcome according to side of lesion.

The frequency of behavioural difficulties after TBI may be high in part due to pre-injury status, as behavioural adjustment problems are themselves a predictor of TBI in children [40, 41]. In addition, family adjustment problems before the injury increase the likelihood of post-injury behaviour and psycho-social problems in children [42]. The thesis that pre-injury personality and psycho-social problems are substantial contributors to post-injury problems has also been advanced in the adult TBI

literature [11, 43–45]. In contrast, Tate's [35, 45] data suggest that pre-injury behaviour problems are not good predictors of post-injury psychosocial adjustment and that the frequency of pre-injury problems has been over-stated in the literature. Nevertheless, poorly controlled behaviour and problematic social interaction are common after TBI and have long been linked to difficulty in family reintegration and educational, vocational, social and avocational pursuits [9, 46–50].

Unlike most neurobehavioural consequences of TBI that improve over time, irritability, aggression and other behaviour problems may worsen, both in children [51, 52] and adults [5, 15]. Long-term outcome studies of children with TBI have suggested that behavioural outcome later in childhood and into the adult years tends to be worse than predicted shortly after the injury [53, 54]. Furthermore, the few children with relatively 'pure' pre-frontal injuries who have been described in the literature have, with few exceptions, developed increasing behaviour problems over the years after their injuries. Eslinger et al. [55] reviewed the nine available long-term case studies of children with isolated pre-frontal injury and concluded that impairment of 'social executors' was the most consistent and critical concern with this population and that new social difficulties may continue to emerge through adolescence.

In the case of both children and adults, escalating behavioural difficulties may be a combined result of neuropathology and the frustrations associated with poor performance in school or on the job, job loss, social isolation and activity restrictions [8]. Worsening behavioural profiles over the developmental years in children with early injury may be in part a function of increasing academic demands and expectations for self-regulated behavior [20, 52, 53]. Kim et al. [56] argued that acute onset irritability and aggression may be directly related to cortical lesions whereas delayed onset problems are likely to be associated at least in part with poor adjustment, mood disorders and the like.

Need for effective treatments: Alternative approaches

The persistence and magnitude of social and behaviour problems after TBI underline the importance of effective treatments. In the following sections, the existing evidence for intervention is reviewed and summarized in the form of practice recommendations. These recommendations are intended to be cross-disciplinary, because social and behavioural problems affect all aspects of life. For the purposes of this review, studies were placed into one of three categories, based on their intervention procedures: primary use of contingency management procedures (CMP), generally

associated with traditional applied behaviour analysis (ABA); primary use of proactive, antecedent-focused procedures, generally associated with positive behaviour interventions and supports (PBIS); or a relatively balanced combination of procedures. Contrasting central themes of traditional ABA and PBIS approaches are summarized in Table I. Ongoing controversies about the core features of ABA and PBIS and the relation between the two models of behavioural service delivery are further elaborated in the Discussion section.

Method

Search procedure and questions to be addressed

The following databases were searched using combinations of the terms traumatic brain injury, acquired brain injury, brain injury, behaviour disorders, intervention, treatment and rehabilitation: Medline, PsychInfo; Psych Articles, PsychBite, Google Scholar, ERIC. Additional papers were identified using citations in the articles identified through these databases. Only English language articles containing a description of research methods (including intervention methods) and quantitative outcome data were included in this review. The following exclusionary criteria were used in selecting articles for review: (1) articles not addressing behavioural interventions for behaviour disorders, (2) theoretical articles or descriptions of treatment approaches, (3) review articles, (4) articles describing studies whose participants were not primarily TBI, (5) case studies without quantitative data, (6) studies described in book chapters and (7) articles primarily describing pharmacologic intervention. Expert opinion, sometimes considered evidence in evidence reviews, was excluded. For inclusion, studies were required to focus on individuals with TBI. Individuals with acquired brain injury other than TBI who were included in a TBI-focused paper were also included in this review if their impairment profiles resembled those of individuals with TBI. The search resulted in 65 papers that described database-based intervention studies, with 172 participants receiving the experimental intervention. Table II lists the questions that were addressed in this evidence review.

The 65 studies that met the selection criteria were obtained and reviewed. The Appendix is a table of evidence that provides the reference for each article and summarizes the information from each study. In the Appendix, the studies are listed in chronological order. There are 16 columns of data in this table of evidence: *General Information*: (1) The reference citation, (2) Study design, (3) Classification of the level of research; *Participants*: (4) Descriptions of

Table I. Contrasting themes: traditional applied behaviour analysis and positive behaviour interventions and supports.

Traditional ABA	Positive behaviour interventions and supports
<p><i>Focus and goals</i> Focus on specific behaviours, with the goal of increasing the frequency of positive and decreasing the frequency of negative behaviours. Primary focus on external control of behaviour via systematic manipulation of consequences.</p>	<p>Primary focus on life-style change satisfactory to the individual and important others in that life. Secondary focus on specific behaviours. Primary focus on internal control of behaviour and behaviour change via manipulation of antecedents, including both remote and internal antecedents to behaviour. Often combined with cognitive and executive system intervention.</p>
<p><i>Assessment</i> Functional behaviour assessment, ideally conducted by behaviour specialists in analogue (i.e. experimentally controllable) environments.</p>	<p>Functional behaviour assessment, ideally conducted in natural environments and involving collaboration among staff, family and the individual. Assessment of background setting events (including general life style, internal states of the person and environmental facilitators and barriers) is mandatory.</p>
<p><i>Intervention modalities and methods</i> Primary use of contingency management (i.e. systematic and planned manipulation of consequences), designed to increase (positive and negative reinforcement) or decrease (extinction or punishment) specific behaviours. Procedures include differential reinforcement of positive behaviours, of behaviours incompatible with the negative behaviour or of low rates of negative behaviours; token economy procedures (awarding tokens for positive behaviours that can be cashed in for rewards), extinction procedures (e.g. planned ignoring of negative behaviours, time-out, time out on the spot), response-cost procedures (e.g. losing points for negative behaviour). If any focus on antecedents, typically immediate antecedents (e.g. specific provocation, environmental conditions, instructions/demands, etc). Often primary use of extrinsic reinforcers (e.g. food, stickers, tokens) not logically and naturally related to the targeted behaviour.</p>	<p>Primary focus on control of antecedents, including both remote (e.g. negative events at an earlier time) and internal (e.g. sense of loneliness, perceived failure, physical pain) setting events, with the goal of making background setting events as positive as possible and in this way increasing the likelihood of positive behaviour. PBIS procedures include meaningful environmental structuring, adjustment of tasks and expectations to ensure success, provision of meaningful and well understood daily routines, assurance of adequate amount of choice and control, engagement in meaningful activities, engagement with desired people, positive behavioural momentum before difficult tasks, positive communication from communication partners, teaching positive communication alternatives to negative behaviour, natural and logical rewards for positive behaviour.</p>
<p><i>Organization of intervention</i> Specific behaviours often taught in a sequential manner: acquisition then stabilization/fluency then transfer/generalization.</p>	<p>Specific behaviours often targeted in natural settings and in the context of natural activities from the outset (with support); thus transfer/generalization facilitated from the outset.</p>
<p><i>Setting, content, providers</i> Intervention often provided in 'behaviour management' settings (e.g. segregated classroom, clinic, residential centre); Intervention largely delivered (at least in the acquisition stage) by behaviour specialists.</p>	<p>Intervention often and ideally provided in natural (home, work, school) community settings, with primary providers being those people who are natural communication partners in those settings (e.g. family members, work or school staff, peers), supported by specialists.</p>

participants, (5) Number of participants; *Intervention*: (6) Type of intervention, (7) Specifics of intervention, (8) Duration, (9) Setting, (10) Provider; *Outcomes*: (11) Dependent variables, (12) Reliability, (13) Results, (14) Maintenance, (15) Transfer, (16) Social validity.

Reliability of data extraction was questioned only in classifying studies into one of three intervention categories: primary use of contingency management procedures (associated with traditional ABA), primary use of PBIS procedures or a relatively balanced combination of procedures. Reliability was tested at the beginning of the review by independent classification of 10 studies by two investigators. There was agreement on nine of the 10 studies (90%) and

agreement was reached on the 10th following a brief discussion. Subsequent to this formal reliability test, an additional 40 of the studies were independently classified by two investigators, with agreement achieved in each case. There were no disagreements among readers in classifying study design, level of research or other review data.

Results

Who are the participants receiving behavioural interventions?

Consistent with the epidemiology of TBI, virtually all of the participants were children, adolescents or

Table II. Questions addressed in the evidence review.

-
1. Who are the participants receiving behavioural interventions?
 - What is the diagnosis?
 - What is the severity of injury?
 - What is the participant's age?
 - What is the time post-injury?
 - Are there dual diagnosis or co-morbidity factors?
 - What is the participant's cognitive profile post-injury?
 2. What interventions were implemented?
 - What is the focus of intervention?
 - What is the treatment duration?
 - What is the treatment setting?
 - Who are the providers?
 - Are there multiple components to the treatment, including different categories of treatment (e.g. co-occurring pharmacologic and behavioural treatments)?
 3. What are the intervention targets and outcomes?
 - What are the intervention targets (dependent variables)?
 - Are there measures suggesting socially, educationally or vocationally significant improvements, maintenance of improvements over time, transfer to other settings or activities?
 4. What are the methodological concerns?
 - What is the study design?
 - Are there adequate control procedures (internal validity)?
 - Are reliability and validity of measurement addressed?
 5. Are there standards of care, guidelines or intervention options that can be supported by the evidence?
 - Are there findings that warrant practice recommendations?
 - Are there clinically applicable trends in the literature?
-

Table III. Participants' age.

Age range	Number of participants ($n = 126$ out of 172 total with age specified)
0–5 years	2
6–17 years	54
18–29 years	44
30–39 years	15
40–49 years	9
50–59 years	2

Four studies ($n = 46$), including Carnevale [58] ($n = 11$), Eames and Wood [22] ($n = 24$), Medd and Tate [62] ($n = 8$) described the participants as 'adults' without specifying age.

young adults under age 50, as is shown in Table III. Fifty-four (31%) were children or adolescents under age 18; 116 (68%) were adults age 18 or over. The somewhat larger percentages of children in the PBIS studies (29%) and combined PBIS/CMP studies (43%) than in the pure CMP studies (23%) may reflect the fact that growing interest in rehabilitation of children with TBI has coincided with the evolution of PBIS as a movement within behavioural psychology. Seventy per cent of the participants were male, again reflecting general trends in the epidemiology of TBI.

In most cases ($n = 154$), the primary diagnosis was TBI. Exceptions included anoxia ($n = 4$), subarachnoid haemorrhage ($n = 3$), encephalitis ($n = 2$), diabetic coma ($n = 2$) and one each from the following categories: meningitis, fronto-temporal

glioma, corpus collostomy and acquired hydrocephalus. In three cases, the aetiology was not reported. Aetiologies other than TBI were included only if the impairments and associated disabilities resembled those that are common after TBI and the individual was included in a study that focused on TBI. Almost all of the participants had injuries judged to be severe, although criteria for severity of injury were often not given. One participant was said to have a moderate TBI. The 16 experimental participants in the Wade et al. [57] study were described as having moderate-to-severe injuries, while the 11 participants in the Carnevale [58] study were said to have mild-to-severe TBI.

In the minority of cases in which specific site of lesion information was included, frontal lobe injuries predominated ($n = 25$). However, the high frequency of executive function impairment among participants for whom no localizing information was reported would suggest a much higher proportion of frontal lobe injuries. Specific pathophysiologic information was regrettably omitted from most of the published reports.

Time from injury to initiation of treatment varied from 2 weeks to 13 years, with most individuals at least 1 year (92 of the 128 with time post-injury specified) and many several years post-onset, thus controlling for early spontaneous recovery (see Table IV). Most of the studies in which the participants were within weeks of the injury were designed in part to demonstrate that

Table IV. Time from injury to initiation of the studied behavioural intervention.

Length of time from injury to studied intervention	Number of participants ($n = 172$)
0–3 months	17
3–6 months	4
6–12 months	10
1–2 years	15
2–5 years	31
5–10 years	12
more than 10 years	3
not reported	19

Four group studies reported only injury-to-onset of intervention means: Carnevale [58]: $n = 11$, mean = 10 years; Eames and Wood [22]: $n = 24$, mean = 4 years; Medd and Tate [62]: $n = 8$, mean = 3 years; Wade et al. [57]: $n = 16$, mean = 9 months.

Table V. Number of participants with identified behaviour problems ($n = 144$ with type of behaviour problems specified; the total number exceeds the number of participants because many were reported to have more than one type of problematic behaviour).

Type of behaviour problem	Number of participants
Unspecified aggression	24
Physical aggression	51
Verbal aggression (threats, obscenities, etc)	46
Uncontrolled verbal output (e.g. demands)	12
Anger management problems	8
Self-injurious behaviour	6
General impulsiveness, disinhibition, disruptiveness	27
General non-compliance, refusal to participate	26
Sexually inappropriate talk or activity	13
General anxiety	4
Unsafe behaviour	4
Poor hygiene	2

One each: decreased frustration tolerance, apathy, compulsive or stereotypic behaviour, general agitation, general irritability, reduced initiation, pseudo-seizures.

Group studies in which specific behaviour problems were not reported: Carnevale [58]; $n = 11$; Wade et al. [57]: $n = 16$.

behavioural learning can occur during post-traumatic amnesia [59].

Table V presents the number of participants who were identified with specific types of behaviour problems. Approximately two thirds of the participants whose problematic behaviours were described (98 out of 144) were said to engage in aggressive behaviour. If participants identified as having sexually inappropriate behaviour, self-injurious behaviour, anger management problems and general impulsiveness/disruptiveness are added to this total, it becomes clear that the vast majority of individuals

reported in the behavioural intervention literature had largely externalizing symptoms. Indeed only two participants out of the total of 172 were explicitly identified with predominantly internalizing symptoms (i.e. apathy, initiation impairment). While it might be that some additional cases of non-compliance were a result of internalizing conditions, this is unlikely given the other symptoms attributed to those patients. Furthermore, it may be that some of the participants in the Wade et al. [57] study had internalizing symptoms; specific symptoms were not described.

The authors frequently provided insufficient information to document dual diagnoses (e.g. substance abuse or cognitive and psychiatric diagnoses associated with behavioural disorders after TBI). In the case of studies in which participants were well described, most had some degree of cognitive impairment (e.g. attention, organization and/or memory problems) and executive system impairment (e.g. impulsive behaviour, poor planning, self-monitoring and problem-solving) associated with their behavioural difficulties. However, it was rarely established that the behavioural concerns were a direct consequence of the cognitive and executive system impairments and in many cases co-existing impairments were not effectively described.

What types of studies were conducted

Studies were classified using the following system, consistent with many reviews in the health-related professions [60, 61]: Class I: Randomized controlled trials (RCTs) with effective control procedures; Class II: Group studies with inadequate control procedures; Class III: Single-subject experiments with effective experimental controls; Class IV: Uncontrolled case studies, case series and single-subject designs with only AB procedures (baseline followed by intervention). This system deviates from commonly used evidence classification systems in medicine (e.g. Oxford Centre for Evidence Based Medicine: http://www.cebm.net/levels_of_evidence.asp) because of the importance of single-subject experiments in behavioural studies. Single-subject studies are typically not included in medical classification systems.

Two of the 65 studies were Class I RCTs: Medd and Tate [62] with eight adult participants in the experimental group and Wade et al. [57] with 16 paediatric participants in the experimental group. Both Class I studies used PBIS procedures. Two of the studies were Class II uncontrolled group studies that compared pre-intervention with post-intervention measures [22, 58]. Consistent with the experimental literature in behavioural psychology, a majority of the papers ($n = 36$) reported results of

Table VI. Relative emphasis of traditional ABA and PBIS behavioural intervention studies in TBI rehabilitation over the past 25 years.

Intervention study: <i>n</i> = 65		1980–1989	1990–1999	2000–2005
Traditional ABA	Studies	9	14	3
	Participants	38	27	5
Combined ABA/PBIS	Studies	2	14	6
	Participants	3	37	10
PBIS	Studies	0	6	11
	Participants	0	13	39

one or more Class III single-subject experiments. Single-subject methods included the following experimental designs: reversal, changing treatment and multiple baseline across subjects, settings and treatment targets. The remaining 25 articles reported Class IV case studies or case series (i.e. no or minimal experimental controls). A conservative decision was made to classify all single-subject AB designs (i.e. baseline followed by treatment phase) as Class IV (Case Studies) because of the weak experimental control in such studies. It should be noted, however, that in some cases [63] the data graphs reveal such a sharp improvement in functioning with the introduction of treatment that a causal relationship can reasonably be inferred. Thus, the evidence base for behavioural interventions may be somewhat stronger than is suggested by this review.

What interventions were implemented?

Treatment type. As can be seen in Table VI, 26 of the studies used primarily contingency management procedures, 22 used a roughly equal combination of CMP and PBIS procedures and 17 used primarily PBIS procedures. In studies published before 1990, the traditional CMP approach clearly dominated (nine CMP; two combined; zero PBIS). In the 1990s there was increasing use of PBIS procedures and they have dominated the research literature since 2000 (11 PBIS studies (39 participants), six combined (10 participants), three CMP (five participants)).

Both of the RCTs in this review used PBIS procedures. Wade et al. [57] implemented a family-centred proactive problem-solving intervention programme to prevent problem behaviours in children with TBI. Medd and Tate [62] successfully used a variety of antecedent control procedures, including stress inoculation training, self-awareness training and proactive anger management strategies, to treat adults with anger management disorders after TBI.

Treatment duration and frequency. With respect to treatment duration, the range was from 2 weeks to

10 years. The majority of interventions were in place for several weeks, generally in the range from 1–6 months. One study did not report treatment duration and several reported in sessions rather than days or weeks. In some cases, the duration of the experimental manipulation of the intervention was specified, after which the intervention conditions were again implemented. Thus, the total duration of the intervention in such cases is unknown. Frequency of intervention is not relevant in the case of approaches that are in part environmental in nature, with all relevant staff and/or companions trained to implement the intervention throughout the day. This was the case with most of the 65 studies.

Treatment settings and providers. Treatment settings included acute and post-acute residential rehabilitation facilities, community-based rehabilitation programmes, schools, homes and other community settings. The reports rarely distinguished among types of residential programme (e.g. acute rehabilitation, post-acute residential rehabilitation, long-term care facility, residential school). Fifty-two of the studies occurred in residential settings, with the remainder taking place in family homes, medical day programmes, outpatient clinics, community school classrooms, special school classrooms or vocational training settings. Each of the three types of intervention (CMP, PBIS, combined) was used in residential settings. On the other hand, only PBIS and combined interventions were used in community settings (e.g. homes, community schools).

Providers of the treatment services included licensed clinicians, paraprofessionals, family members and other companions. In most cases, the interventions were delivered by paid staff, although many of the reports failed to specify the specific roles of the individuals who delivered the behavioural interventions or their training. Eleven of the studies made specific note of training given to everyday communication partners (e.g. family members, teaching assistants, nursing assistants) to deliver the intervention within natural settings.

Multi-component interventions. In most cases, the treatment had more than one component (e.g. differential reinforcement of alternative behaviours combined with response-cost procedures; positive communication training combined with cognitive supports such as advance organizers), thus ruling out the possibility of assigning effects to one specific component.

What are the intervention targets and outcomes?

As would be expected in most studies of behavioural interventions, the dependent variables (desired outcomes) were in most cases increases or decreases in specific behaviours. Fifty-eight of the 65 studies targeted increases or decreases in specific behaviours: 34 targeted just decreases in negative behaviours, nine targeted just increases in positive behaviours, 15 targeted both. Additional dependent measures included standardized behaviour scales (five studies), customized rating scales (two studies), measures of support required for positive behaviour (five studies), placement (e.g. in a less restrictive setting; one study) and customized questionnaire (one study). Targeted negative behaviours included acts of physical and verbal aggression, sexually inappropriate behaviour, uncontrolled verbal and vocal output, disruptive behaviour and self-injury. Targeted positive behaviours included compliance with therapy regimens, attendance, completion of activities of daily living on task behaviour, appropriate communication, amount and/or correctness of work completed, amount of food/liquid intake, weight gain and successful role plays of social skills. Impairment-level measures (e.g. results of neuropsychological tests) were not used as a measure of the effectiveness of intervention.

Are there measures suggesting changes in functional behaviors, maintenance of changes and transfer to other settings? All of the studies demonstrated improvement in at least one measured outcome (dependent variable). Most of the studies that tracked negative behaviours demonstrated reduction in frequency to zero or at least contextually acceptable low levels of frequency. Because behaviour change has little practical significance unless it is generalized and maintained over time, it is particularly important to show generalization to a variety of natural tasks and settings, maintenance over time and effects on educationally, vocationally or socially meaningful outcomes. That is, documentation of improvements at the level of body structure and function (impairment) are socially meaningful only if associated with benefits to the participant and/or everyday support people at the level of functional activities and participation in personally meaningful daily living.

Forty-two of the 65 studies included follow-up reports (either quantitative or anecdotal). In each case, at least some maintenance of treatment gains was reported. Follow-up duration ranged from five sessions to 8 years, with most in the 1–12 month range. The absence of follow-up data in 23 of the studies is a substantial shortcoming of this evidence base.

With respect to transfer of treatment gains to non-treatment settings, activities or people, 21 of the studies reported some positive transfer. Five reported no transfer, none during the experimental treatment or a need for ongoing programming after discharge. One group study reported mixed results. Thirty-eight studies failed to include transfer or generalization data.

Social validity has been construed to mean either or both of the following: (1) functional importance of treatment gains for the individual's educational, vocational, social and/or independent living success; (2) the ease with which the intervention can be implemented and its value as judged by relevant everyday people in the life of the person with TBI. Thus, an intervention could be judged to be socially valid if it resulted in the participant being discharged to a less restrictive setting, in greater engagement in the rehabilitation process, in maintenance of a job or school placement that had been threatened by negative behaviour or in an increase in number and variety of successful social interactions. The intervention might also be judged to be socially valid if family members or other everyday companions found it easy to implement and useful. Forty-five of the 65 studies reported some sort of social validity information, with all but one reporting positive findings. In many cases, social validity was implicit in the study's dependent variable, for example, decreasing frequency of absenteeism or of sexually intrusive behaviours. The single study with a negative social validity finding reported that the family found the programme difficult to implement. This was a CMP study that used extinction procedures, such as time out on the spot and planned ignoring of screaming.

Are there methodological concerns?

In all of the reviewed studies, some improvements in the behaviours targeted by the intervention were noted. Interpretation of these uniformly positive findings is clouded by (1) the small number of studies with Class I evidence ($n=2$), (2) failure to report measures of generalization and maintenance of treatment gains in many cases, (3) anecdotal reference to failed interventions that were not published as studies and were therefore not included in this systematic evidence review, (4) evidence from

studies of other populations showing that certain behavioural interventions are consistently ineffective for specific behaviour problems, and (5) possible subject selection bias, which is an inherent weakness of single-subject experiments and case studies. Methodological concerns 2–5 are addressed in the Discussion section which includes a description of the inherent strengths and weaknesses of single-subject experiments.

Discussion

Sixty-five studies of behavioural interventions for individuals with behaviour problems after TBI were reviewed. All of the studies yielded positive findings, but methodological weaknesses are common in this body of evidence. In the sections that follow, important aspects of this literature are discussed.

Participants

There is great variety in time post-injury of the studied participants. The fact that a majority of the participants were more than 1 year post-injury when behavioural intervention was initiated probably reflects the documented phenomenon of intensifying behavioural concerns over time after severe TBI, particularly with damage to the frontal lobes. It also bolsters the evidence by ruling out spontaneous recovery as the cause of improved functioning. Most of the studies in which the participants were within weeks of the injury were designed in part to demonstrate that behavioural learning can occur during post-traumatic amnesia, thus laying a foundation for deliberate application of behaviour management principles during this early period of recovery [59].

The fact that only two of the 172 participants were explicitly identified with internalizing symptoms deserves attention. The frequency of initiation impairment, apathy, social withdrawal and/or depression is reported to be high in the TBI outcome literature and the real-world effects of these internalizing disorders are substantial [19, 64]. Using DSM IV criteria, Hibbard et al. [19] found that 61% of 100 adults with TBI had experienced major depression at some time during the 8 years since their injury. This contrasts with only 17% who had a pre-trauma history of major depressive disorder.

Therefore, it is worth speculating about the reasons for the extreme under-representation of internalizing disorders in the behavioural treatment studies. Some combination of the following possibilities may contribute to the explanation: (1) Individuals with internalizing symptoms are less likely to be referred to behaviour specialists or facilities designed to serve individuals with severe

behaviour disorders. Externalizing disorders, such as aggression, are typically judged to require immediate attention, whereas internalizing disorders, such as apathy or withdrawal, are often judged to be less pressing. Consistent with this speculation, Winkler et al. [15] found that externalizing problems were strongly associated with poor community integration, whereas internalizing problems (e.g. loss of motivation) were not. (2) Clinicians who rely heavily on contingency management may experience frustration in treating individuals who engage in very little behaviour that can then be consequated. (3) Pharmacologic options may be the treatment of choice for internalizing disorders [65]. (4) It may be that internalizing disorders are in general more resistant to treatment than externalizing disorders, although the Wade et al. [57] study demonstrates that internalizing symptoms can be lessened with a family problem-solving intervention for a paediatric population. (5) Finally, externalizing behaviours are typically framed in behavioural terms, creating a natural tie to behavioural interventions, whereas internalizing behaviours are more often framed in cognitive or medical/psychiatric terms.

Of interest to specialists in communication disorders, 77 of the 144 participants with specifically described behaviour problems had problematic communication among their targeted behaviours. Communication-related behaviour problems include verbal aggression, excessive or disruptive talk, extreme profanity, sexually inappropriate interaction, screaming and verbal outbursts. If other negative behaviours that serve a communication purpose (e.g. physical aggression functioning as escape communication) are added to this list, then a large majority of the problematic behaviours targeted in the behavioural intervention literature have a communication dimension, thereby inviting the attention of communication specialists.

Interventions

Over the past 20 years, the field of applied behaviour analysis (ABA) has evolved into two interestingly different approaches to assessment and intervention, referred to in this article as CMP or traditional ABA, highlighting contingency management procedures, and PBIS [25, 66, 67]. Controversies persist over the degree of difference and exact relationships between these two approaches. For example, Carr et al. [67] assert that PBIS is a new social science with an innovative theoretical foundation and novel intervention procedures, whereas Johnston et al. [66] insist that there is nothing in PBIS theory and practice that cannot be found in the ABA literature. The approaches were distinguished in this review because marked differences in behavioural

interventions described in the research literature should not be lost in an evidence review.

Traditional ABA, which has a much longer history of procedural development and research than PBIS and is supported by an extensive research literature with a variety of clinical populations, emphasizes—but is not restricted to—the management and modification of behaviour by deliberately manipulating consequences. This contingency management approach is based on the operant principle that behaviours increase or decrease in frequency as a result of positive and negative consequences. A meta-analysis of 99 classroom-based contingency management experiments in reducing disruptive behaviour with diverse clinical populations showed that positive reinforcement, verbal praise, token economies (receiving tokens for positive behaviour that can later be ‘cashed in’ for desirable rewards), response-cost procedures (e.g. losing tokens or points for negative behaviour) and time out from reinforcement have all been demonstrated to be effective in reducing problem behaviours in some contexts (moderate effect sizes). Combinations of these intervention strategies have been shown to increase the effect size [68].

In the current review, the following contingency management procedures were used effectively in at least one study:

- positive reinforcement (including differential reinforcement of positive or other behaviours, differential reinforcement of behaviours incompatible with the negative behaviour and reinforcement of low rates of negative behaviours),
- negative reinforcement (e.g. removal from aversive conditions following the targeted behaviour),
- extinction (including time out from reinforcement, time out on the spot, planned ignoring, redirection), and
- punishment (e.g. response-cost procedures).

In many cases, including studies conducted at the Kemsley Unit in England, specific contingency management procedures were organized within a facility-wide token economy programme. When facilities use such programmes, staff are trained to reward individuals for positive behaviour with tokens that can later be ‘cashed in’ for desirable activities, objects or food. Despite published successes (see evidence table), in some cases, specific contingency management procedures (e.g. time-out procedures applied to escape-motivated negative behaviour) or general token economy programmes have been found to be ineffective [69].

PBIS emphasizes—but is not restricted to—the management and modification of behaviour by manipulating antecedents, including both immediate and remote setting events (e.g. a troubling

interaction earlier in the day), as well as external and internal setting events (e.g. loneliness). The central themes in this framework are proactive prevention of negative behaviour and systematic facilitation of repertoires of positive behaviour that render the negative behaviours irrelevant [67, 70, 71]. Errorless learning (or errorless compliance) is often a goal of PBIS procedures [72, 73], making this framework theoretically consistent with the growing neuropsychological literature on the importance of errorless learning for individuals with significant explicit memory impairment [73–76].

The following PBIS procedures, often used in combination, were found to be effective in at least one of the reviewed studies:

- specifically planned environmental structuring,
- proactive adjustment of tasks and expectations to ensure success,
- provision of meaningful and well understood daily routines (possibly including external graphic organizers to ensure orientation to tasks, schedules and routines),
- assurance of adequate amount of choice and control,
- engagement in personally meaningful activities,
- engagement with desired people,
- planned development of positive behavioural momentum before difficult tasks,
- assurance of errorless learning with adequate antecedent supports/prompts (including ‘precorrections’),
- planned assurance of positive, supportive communication from communication partners, and
- proactive development of positive communication alternatives to negative behaviour.

Clinicians working within the PBIS framework do not neglect consequences. However, they tend to highlight natural and logical rewards for positive behaviour (e.g. a good grade as a reward for studying hard) as opposed to the artificial rewards often associated with token economy programmes.

The following neuropsychological reasons for using PBIS procedures for individuals with behaviour disorders after TBI have become increasingly salient in the neuroscience research literature over the past 20 years and should be considered when weighing the evidence for the contrasting approaches: (1) Ventral frontal lobe injury, associated with disinhibition and weak reinforcement learning, is common in TBI and reduces the capacity to learn from consequences and to inhibit behaviours based on past consequences [77–79]; (2) dorsal (superior medial) frontal lobe injury may include initiation impairment, which also reduces the effectiveness of contingency management [80, 81]; (3) right hemisphere frontal lobe injury, in combination

with damage to the limbic system, impairs social perception [33, 82, 83], which also reduces the effectiveness of contingency management; and (4) finally, a history of failure and frustration, possibly combined with oppositionality (common among individuals with TBI), may further reduce the effectiveness of contingency management.

Some degree of environmental structuring is undoubtedly a component of all programmes that serve individuals with behaviour disorders after TBI. In this review, antecedent control procedures of this sort were classified as PBIS if they were highlighted as specifically implemented procedures in the intervention programme. Cognitive-behavioural procedures (e.g. TBI education, stress inoculation training, self-talk training, self-removal from stressful situations) were also classified as PBIS because the focus is on preventing negative behaviour with advance support and antecedent manipulations.

A concern about the PBIS framework has been raised on the grounds that its support procedures (e.g. reducing performance expectations) may result in the individual's dependence on unusual levels of environmental support for successful behavior [84, 85]. The PBIS response to this legitimate concern is that supports must be systematically withdrawn as treatment progresses and as the person acquires increasing self-regulation and increasingly strong habits of positive behaviour. This treatment requirement is parallel to the requirement of operant conditioning approaches that planned contingencies become progressively more intermittent, randomized and natural as a means of reducing unwelcome dependence on consistent, immediate and tangible reinforcement [86].

Because of the existence of these two philosophically and procedurally disparate orientations to intervention, it is not possible to do a straightforward interpretation of the evidence and derive *specific* intervention standards or guidelines, regardless of the strength of the evidence that may exist for either or both orientations. For this reason alone, this review results in a very general *guideline* (i.e. behavioural intervention in general, not otherwise specified, is supported by the literature) and associated intervention *options*. The historical trend in the intervention literature toward PBIS procedures, together with their theoretical and neuropsychological support, supports ongoing research efforts in this domain.

A further complication in interpreting the results of this review derives from the concern that investigators who highlight PBIS procedures may be insufficiently sensitive to, and therefore fail to document, the impact of contingencies within their interventions, while investigators who highlight contingency management may be insufficiently

sensitive to, and therefore fail to document, the impact of their antecedent manipulations. For example, when PBIS procedures are successful, the participant inevitably experiences a variety of positive consequences, including praise from others, increased domains of activity, positive feelings of success and competence and the like [52, 87]. These contingencies may play a powerful role in modifying the behaviour. Similarly, investigators who describe a strictly contingency management system of behaviour modification often reduce expectations and modify environments and tasks in the early stages of intervention in order to increase the occurrence of behaviour that can then be reinforced [88]. These task modifications and environmental adjustments could be considered antecedent management procedures and may play a more critical role in the intervention than is highlighted in the traditional ABA research reports.

Furthermore, a single behavioural intervention, for example functional communication training (FCT), may be characterized as a PBIS procedure by some investigators [51, 52] and as contingency management by others [89]. From a traditional ABA perspective, FCT is one type of differential reinforcement of functionally equivalent behaviours. For example, escape-motivated aggression may be treated by encouraging the person to say 'I need a break' rather than using aggression for the same purpose and then rewarding him with a break. The same intervention strategy is described by proponents of PBIS as an antecedent management strategy [70, 90].

As an organized approach supported by a coherent theory, PBIS is relatively new and is therefore associated with a smaller research base [67, 71] than is traditional ABA. This review of 65 published studies of the effectiveness of interventions for behaviour disorders after TBI suggests a marked evolution in the direction of PBIS approaches. In the early stages of development in TBI rehabilitation, traditional contingency management procedures were dominant [22], although the early literature also included clinical discussions that highlighted the importance of antecedent management [91]. In recent years, PBIS procedures have increasingly dominated the TBI behavioural literature.

Excluded from this review were three successful single-subject reports in which PBIS procedures (referred to as 'errorless compliance') were taught to parents with TBI so that they could manage the behaviour of their children [72, 73]. Although not directly relevant to the current review, these studies offer evidence for selecting proactive behaviour management procedures to teach to parents with TBI who have children with challenging behaviour.

An evaluation of the efficiency and cost-effectiveness of behavioural interventions is not possible using this body of literature. Information about the effort needed to train staff to implement environmental interventions effectively was rarely included in the published reports. It is interesting to note that all three types of intervention were used in residential settings, whereas only PBIS and combined interventions were used in community settings (e.g. homes, community schools), possibly reflecting the commitment to natural setting interventions within the PBIS framework [92]. Eleven of the studies made specific note of training given to everyday communication partners (e.g. family members, teaching assistants, nursing assistants) to deliver the intervention within natural settings. Eight of these studies were classified as PBIS and three as combined, again illustrating the commitment within the PBIS orientation to behavioural supports within the natural environment.

Multi-component interventions are common in all three types of behavioural rehabilitation and are probably preferable to single interventions, based on meta-analyses with other populations [68] and on the evidence in the current review. In the event that the component interventions are not costly and are considered good practice for other individuals in the setting (e.g. systematic attempts to ensure positive communication and adequate support for successful performance of meaningful tasks), it is not critical to systematically identify the specific contribution of each component to the total treatment effect [51, 52, 87, 93]. In other cases (e.g. combined pharmacologic and behavioural interventions), there is a great advantage in sorting out the relative contributions of the component treatments.

Intervention targets and outcomes

Each of the 65 studies reported some positive outcome across a wide variety of treatment targets. However, the large number of studies ($n=38$) with no reports of generalization is on the surface alarming. This concern is mitigated by the observation that most of these studies were PBIS or combined, with supports provided in most if not all settings throughout the treatment period. Thus, measures of transfer are less critical than they are in cases in which the treatment is provided only in one or a small number of controlled settings and is expected to generalize to novel settings. Nevertheless, reliable and valid measures of transfer of treatment gains should be a goal for future studies of behavioural interventions for this population.

Methodological concerns

Serious methodological concerns weaken this body of evidence.

Inconsistent reporting of generalization and maintenance. Many of the studies failed to include valid indicators of maintenance of treatment gains over time and transfer to non-treatment settings and activities. Modifying behaviour under strictly controlled conditions of intensive intervention over a relatively short period of time is far less difficult than generating enduring changes that transfer to non-treatment settings and conditions. Therefore, a behavioural intervention should be considered successful only if it results in meaningful improvements that are observed in a variety of life circumstances and are maintained over time. Presumably in response to this concern, studies have increasingly been conducted in everyday community settings [58], family homes [63] and community schools [51, 52, 87, 93], to avoid the historic challenge of transfer of training [94].

Unreported failures of behavioural interventions. Among the reviewed articles, several stated that behavioural interventions (often unspecified) had failed prior to the successful experimental intervention described in the paper. For example, Alderman [69] reported successful use of satiation through negative practice to decrease shouting as an escape behaviour. However, prior to this successful intervention, the participant had been unsuccessfully treated with a general token economy system and then with an extinction ('time out') procedure. Neither of these failed interventions was separately reported in a non-anecdotal manner and therefore they do not appear in this evidence review.

Zencius et al. [95] similarly documented the ineffectiveness of a popular contingency management procedure (i.e. monetary rewards for compliance) with a participant who later responded well to other procedures. Additional papers in this review similarly reported failure of traditional contingency management procedures prior to the successful single-subject experiment with PBIS procedures [89, 93, 96, 97]. Possibly unsuccessful intervention experiments may be aborted because the individual changes setting (e.g. is transferred to a psychiatric hospital), unexpected pharmacology changes confound the study or the data collection system fails. Thus, intervention failures or potential failures are unlikely to be reported, jeopardizing generalizations from single-subject research on the grounds of subject selection bias.

Inherently problematic behavioural interventions. Caution in interpreting this apparently positive body of literature is further recommended because some behavioural interventions are known to be consistently ineffective or even counter-productive for certain individuals. For example, 'time out from reinforcement' procedures predictably increase rather than decrease challenging behaviours that are *escape motivated*, for the obvious reason that removal from a situation following escape-motivated behaviour reinforces the behaviour that is purportedly targeted for extinction [69, 98]. For example, if screaming during therapy serves the function of ending therapy, then the behaviour will likely increase in frequency if it is rewarded with removal from therapy. Other interventions (e.g. token economies, response cost) presuppose a degree of stimulus-response control that may not be possible in most community settings [99]. For these reasons, the same clinicians working within a single treatment setting (the Kemsley Unit in England) effectively used a variety of alternative treatment procedures for different patients with varying behavioural and cognitive profiles. Similarly, many cognitive-behavioural procedures are predictably ineffective for individuals with profound cognitive impairment, who may become confused and agitated with procedures beyond their comprehension.

Inconsistent reporting of reliability of measurement. Reliability of observation/measurement is especially critical in behavioural intervention studies because change is rarely measured using standardized tools with established reliability. Rather the dependent variables—the target behaviours—are typically defined in operational terms, observed and counted. Inter-observer reliability is therefore essential for meaningful interpretation of the results. Fifty-eight of the 65 studies in this review used customized behaviour counts or intensity measures ($n = 34$ just negative behaviours; $n = 9$ just positive behaviours; $n = 15$ some combination of negative and positive behaviours). Only five studies used standardized behaviour scales with documented reliability. Of the remaining 60 studies, 24 reported adequate reliability, generally over 90% inter-observer agreement. Of the 36 studies that failed to establish reliability of measurement, one was Class II, 13 Class III and 22 Class IV case studies. Inconsistent reporting of reliability stands out as a weakness of this evidence base.

Inconsistent reporting of validity of measurement. Validity of dependent measures is rarely a concern in behavioural studies. In most cases in this review, the dependent variable was either a negative

behaviour targeted for extinction or a positive behaviour designed to replace or serve as a functional equivalent of the negative behaviour. In these cases there is little question about the meaningfulness of the relation between the measure of outcome and the real-world goal of the intervention. In this sense, validity is a strength of this body of evidence. However, 20 of the 65 studies failed to describe social validity, identified as the personal meaningfulness or importance of the measured changes, the evaluation of the behavioural changes by relevant individuals in the environment or the evaluation of the ease with which the intervention can be implemented.

Single-subject experiments in evidence-based practice: Strengths and weaknesses. A majority of the evidence articles in this review (36 of 65) used single-subject (SS) methodologies, common in behaviourally oriented research. Despite their rigorous experimental methodology, SS experiments are generally considered weak (Class III) evidence for population evidence statements because of their obvious problem with external validity; it is impossible to infer from one (or a small number) to most or all members of a clinical population. In support of SS experimental methodology, Horner et al. [100] have proposed that interventions supported only by SS research can be considered 'evidence based' if they meet the following conditions: a minimum of five SS studies that (a) meet acceptable methodological criteria and are published in peer-reviewed journals, (b) are conducted by at least three different researchers across at least three different geographical regions and (c) include at least 20 participants. Based on the criteria of Horner et al., both CMP and PBIS interventions are 'evidence based' in their application to individuals with behaviour problems associated with TBI.

It is worth noting that a rigorous, well-designed SS experiment may yield scientifically more solid evidence for its specific conclusion (i.e. that the intervention caused improved performance in the studied individual) than a randomized controlled trial yields for its conclusion (i.e. that the intervention causes an average improvement in performance across a sub-group of members of the studied population) [101].

However, even accumulations or meta-analyses of successful SS experiments fail to support strong population evidence statements because of the subject selection bias inherent in SS research. Clinicians who engage in SS research with individuals with significant behaviour disorders typically select subjects whom they consider good candidates for a specific approach. Furthermore, in cases in

which the intervention experiment begins to fail, the investigator typically aborts the study for ethical reasons rather than persisting and then publishing negative evidence. Therefore, studies with apparently negative findings are not reported in the literature, except in anecdotal descriptions of subjects whose subsequent intervention proved to be successful. Because the purpose of research design is to reduce the potential for erroneous inference due to bias, the subject selection bias inherent in SS research strongly threatens the inference from such studies to general statements about the effectiveness of interventions for clinical populations as a whole.

Despite these important concerns about external validity, SS experiments create an important evidence base and can be interpreted in a way that circumvents the concern about generalization. In relation to clinical decision-making, SS evidence can be used as a valid form of particular-to-particular inference, rather than as an invalid inference from particular (sample)-to-general (population) evidence statements. Particular-to-particular reasoning proceeds as follows: 'If the individual in this SS report benefitted in experimentally verified ways from this intervention, then my client/student/patient, who resembles this individual in all relevant respects, will likely also benefit, whatever the population evidence may suggest'. If a clinician faces a decision for an individual who resembles the participants in successful SS experiments, it may be more rational to choose the SS intervention than one guided by a general population evidence statement, possibly supported by clinical trials in which some of the participants failed to improve. In other words, what is normally considered Class III evidence may trump what is normally considered Class I evidence in decision-making in individual cases [102].

As Montgomery and Turkstra [103] noted, the client is always an 'n of 1' in clinical decision-making and is likely to differ from a study sample in important ways. This clinical reasoning is especially useful in the case of behaviour disorders after TBI because the individuals most in need of long-term clinical services, community support and special education are often excluded from or outliers within clinical trials using group methods (e.g. individuals with serious behavioural challenges or psychiatric diagnoses, co-existing or pre-existing impairments such as learning disabilities, attention-deficit/hyperactivity disorder [104], other psychiatric disorder, substance abuse, unusual life circumstances and the like). Thus, population evidence statements, no matter how well founded, may be *weak* evidence (reasons) for a clinical decision relative to other types of evidence (reasons). That is, the individual for whom a clinical decision is being made may not resemble those participants in a group study who

benefitted from the experimental intervention. Traditional evidence reviews are, therefore, only one among many contributors to rational (i.e. evidence-based) clinical decision-making. Indeed, the strongest evidence (reason) for a specific clinical decision is experimental validation *with that individual* (i.e. trial therapy, diagnostic teaching, experimental behaviour assessment or dynamic, hypothesis-testing assessment) [105].

For these reasons, clinical reviews of SS research may never yield clinical standards of practice or specific guidelines, but nevertheless may yield strong evidence for individual clinical decisions. For such clinical inferences to be justified, the descriptions of subjects and their life circumstances in SS research papers should be highly specific.

Conclusions and recommendations

Clinical recommendations in this report are based on Miller et al. [106] descriptions of *practice standards*, *guidelines* and *options* [107]. These are defined as follows:

- A *practice standard* is a recommendation that reflects a high degree of certainty based on Class I or very strong Class II evidence.
- A *practice guideline* is a recommendation that reflects moderate clinical certainty, based on Class II evidence, or a strong consensus from Class III evidence.
- A *practice option* is a strategy for which the evidence is inconclusive or there is conflicting evidence or opinion.

The accumulated evidence from two Class I, two Class II, 36 Class III and 25 Class IV studies involving 172 participants supports the conclusion that behavioural intervention in general (i.e. not a specific intervention protocol) for behaviour problems after TBI in both children and adults should be considered a *practice guideline* at both acute and post-acute stages of recovery. Individuals with challenging behaviour after TBI should be provided with systematically organized behavioural interventions and supports consistent with the available evidence and based on individualized functional behaviour assessments. Furthermore, *specific* behavioural interventions grouped under the headings CMP and PBIS can be considered *evidence-based treatment options*. Because most of the evidence is Class III or Class IV and intervention protocols vary from study-to-study, stronger recommendations (i.e. practice standards or intervention guidelines) for *specific* behavioural intervention protocols cannot be supported by the available evidence.

The section above on methodological concerns contributes to the conclusion that practice *standards* cannot be derived from this body of evidence. In addition, the two class I studies themselves have methodological weaknesses (e.g. small number of subjects), further weakening the body of evidence.

Because of the neuropsychological rationale for PBIS procedures and a strong trend over 25 years in the direction of this intervention framework, additional studies of PBIS procedures are warranted. Randomized controlled clinical trials may yield increasingly specific guidelines or standards of practice. However, because of the many subject variables within the population of individuals with TBI, it is likely that clinical judgements regarding the appropriate mix of interventions and supports will continue to be required indefinitely, based on functional behaviour assessments, characteristics of the individual and environment (including the potential contribution of everyday support people within that environment) and careful monitoring of response to treatment.

It is reasonable to infer that the 65 reports of successful interventions in this review are associated with informed clinicians making thoughtful clinical decisions based on specific participant characteristics, setting characteristics, available evidence, effective functional behaviour assessments and ongoing attention to the results of intervention attempts. Ylvisaker et al. [108] presented a theoretical rationale for this individualized approach to evidence-based practice in TBI rehabilitation. Functional behaviour assessments and ongoing monitoring of the individual's response to intervention are particularly critical in behavioural rehabilitation. Clinical mindfulness of this sort will continue to be required even as reviews of the research literature yield increasingly strong conclusions about evidence-based practice.

Considerable work remains to be done in the study of behavioural interventions for individuals with TBI. The following questions and recommendations are suggested by the current review. Evidence-based guidelines for the pharmacologic treatment of neurobehavioural disorders after TBI can be found in the recent review by Warden et al. [109].

- (1) What individual presentations of strength and need lend themselves to specific intervention protocols?
- (2) Are there neurodiagnostic findings that would lead to a recommendation of a specific intervention protocol? Specifically, do significant frontal lobe or specifically orbital prefrontal symptoms recommend antecedent

management interventions over traditional contingency management procedures?

- (3) What are the most rational procedures for combining behavioural with pharmacologic interventions? Studies should attempt to identify the relative contributions of pharmacologic and behavioural interventions. All reports should clearly indicate what drugs participants are taking, their dose and frequency and the timing of the behavioural and pharmacologic interventions.
- (4) What are the most rational procedures for combining behavioural with cognitive and executive function interventions? What modifications to cognitive-behavioural interventions are required in the event of cognitive impairment?
- (5) Does the success of behavioural interventions become systematically more difficult to achieve with increasing time post-injury? With increasing severity of behavioural symptoms?
- (6) What are the relative advantages of community-based vs facility-based interventions?
- (7) Which interventions tend to facilitate transfer and maintenance over time? Measures of transfer and maintenance should be part of all behavioural intervention studies. An intervention should be considered successful only if it results in changes that are observed in a variety of life circumstances and are maintained over time.
- (8) Increasing numbers of studies of behavioural interventions implemented in natural community settings would be a welcome addition to the literature, particularly in light of the decreasing reliance on inpatient and other residential treatment options for individuals with TBI.
- (9) What procedures are most effective in orienting and training everyday support people so that they can effectively play their role in behaviour management? The nature of this training and the time required for the training should be included in future reports.
- (10) In reports of single-subject experiments, the participants and their circumstances should be thoroughly described. A primary contribution of SS research is to guide clinicians seeking evidence-based treatments for specific individuals. The SS research literature offers guidance only to the extent that the participants are described in sufficient detail that clinicians can make confident judgements about the similarity of their client to the participants in the SS experiments.

- (11) Reports of single-subject experiments should also indicate what, if any, interventions were attempted unsuccessfully before the successful intervention described in the report. To be accurately interpreted, the literature should reflect failures as well as successes.
- (12) Behaviour specialists should target internalizing as well as externalizing disorders. Even if these interventions prove to be unsuccessful, clinical insight will be gained.

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Appendix.

Reference	Study design	Class of research	Participants	N _{numbers}	Tx Type (CMP, PBIS or combined)	Specifics	Duration	Setting	Provider	Dependent variable	Reliability	Results	Maintenance	Transfer	Social validity
Lincoln (1978)	Case study	IV	P1. 25 y/o female w/severe TBI, crying & non-compliance with therapy P2. Adult male with severe TBI; resistance to walking	2	CMP	P1. Positive reinforcement, time out, informational feedback. P2. Token economy	P1: 12 treatment sessions; P2: 3 weeks	Inpatient Rehabilitation	Staff	P1. Number of PT exercises completed; P2. Increase in walking	NR	P1. Increase in participation in PT. P2. Increase in walking	NR	NR	NR
Eames and Wood (1985)	Group: uncontrolled pre vs post vs follow-up comparisons	III	18 male, 6 female, w/severe brain injury (21 TBI); age 17-64; all at least 1 year post (mean 4) & admitted because of significant behaviour disorders, including extreme aggression	24	CMP	Highly structured programming & a token economy behaviour modification system on the specialized unit; specific interventions not described	NR	Residential post-acute rehabilitation	Staff	Placement; behavioural & ADL ratings: Follow-up: caregiver questionnaires	NR	Placements improved in 2/3s; no improvement in 1/4; Sexual behaviour, aggression, & other behaviours targeted in Tx often increased at F-U, ADL's remained constant; mixed results at F-U in activities, community participation & perception of improvement	Maintained 6-39 months	Mixed results	NR
Tate (1987)	Case study: AB	IV	P1: 18 y/o female, 15 months post-severe TBI, physical, executive function, & behaviour disorders, depression, refusal, aggression	2	CMP	P1: positive reinforcement, token economy. P2: differential reinforcement; tokens & time out	P1: 2 months; P2: 2 months	Inpatient Rehabilitation	Staff	P1: completion of therapy activities. P2: situations in which negative behaviours occurred	NR	Improvement	P1: NR; P2: 2 month follow-up, no increase in negative behaviour	NR	P2: transfer to nursing home for young people
Burke and Westowski (1988)	Case study (implied AB)	IV	24 y/o male > 3 yrs post-severe TBI w/ frontal lobe involvement; cognitive & behavioural disability; intervention occurred after psychiatric hospitalization	1	CMP	multi-component: token economy, redirection, scheduled attention, relaxation training, behavioural contract, memory supports	2 months	Residential rehabilitation	Staff	Frequency of absenteeism from work & disruptive behaviour	NR	Absenteeism reduced to acceptable levels, disruption reduced to zero, used memory aids	NR	NR	NR
Giles and Clark-Wilson (1988)	Case study	IV	3 male, 1 female; age 23-37 yrs; 3-17 yrs post-TBI; severe physical, language, cognitive, & executive system deficits; severe behaviour problems, including verbal and physical aggression	4	CMP	verbal prompting, verbal reinforcement, and TOOT's intervention	5 days/week; 30-60 minute sessions; 8-22 weeks	Residential rehabilitation	Staff	Self-care independence: number of prompts & level of physical assistance	NR	All improved on dependent measures; 2/4 achieved independence with maintenance	6 & 10 months for S1 & S2. NR for S3 & S4	NR	Reduction of staff time; improved relations w/staff

Author(s)	Year	Study Design	Participants	Intervention	Duration	Staff	Measures	Results	Notes				
Giles et al. (1988)	Case study	IV	27 y/o male, 2 yrs post-severe TBI, attention-seeking verbal aggression & circumlocution	verbal prompts, social attention and praise, food reinforcement, TOOTS	8-22 weeks	Staff	Mean length of utterance	NR	Decreased mean length of utterance	NR	NR	NR	Community living possible
Godfrey and Knight (1988)	Case Study	IV	25 y/o male 2 yrs post-severe TBI, frontal lobe injury, significant cognitive & executive function impairment; aggressive & sexually inappropriate behaviour; poor social & adaptive skills	I. Group memory treatment. II. Train interpersonal behaviour & self-help skills (task analysis, hierarchy of steps, antecedent prompts (errorless learning), verbal praise, prompt fading)	5 months	Staff	Measures of cognition & Adaptive Behaviour Scale (psychosocial functioning, adaptive & social behaviour)	NR	No significant changes in cognitive measures; significant improvement in adaptive measures & social functioning; no specific measure of aggression	NR	NR	NR	To community settings w/tx there
Hegel (1988)	SS: Multiple baseline across settings with reversal	III	18 y/o male; 2 months post-severe TBI; mild-moderate cognitive impairments; behavioural disinhibition & apathy	Goal setting & extinction alone were unsuccessful; add contingent token economy system	26 days	Inpatient rehabilitation	Disruptive vocalizations during therapy (as a measure of compliance): % of goals met	>88%	disruptive vocalizations decreased to zero, compliance increased, % of goals met increased with contingent tokens	NR	NR	NR	Increased learning in therapies
Andrewes (1989)	Case study: AB	IV	32 y/o female; 1 month post-anoxia (failed suicide); generalized intellectual impairment; amnesia; limited speech & communication; near continuous screaming	Extinction; time out on the spot-inattention to screaming; DRO; planned reinforcement with attention when not screaming	5 weeks	Inpatient	Percentage of time intervals during which screaming was observed	NR	Target behavior went from 50-100% of intervals to near zero; continued to be at zero at a three month follow-up	3 months	NR	NR	Staff followed programme; but hard for family
Zencius et al. (1989b)	SS: multiple baseline across treatment conditions with reversal	IV	P1: 24 y/o male 6 yrs post-severe TBI; sensory, physical, cognitive, & executive function impairments; job-related initiation & responsibility problems; P2: 24 y/o old female 2 yrs post-severe TBI bifrontal injury; physical, sensory, cognitive, & executive function impairments; non-compliant	P1: phase 1: verbal contract. Phase 2: written prompts. P2: contingent praise; antecedent supports: male escort, specifically given her cane	P1: 16 days; P2: 42 days	Staff	P1: number & duration unauthorized breaks at work. P2: % time using cane & attending therapies	NR	P1: unauthorized breaks reduced to zero. P2: contingent praise & antecedent supports increased cane use to 100%; contingent money reduced cane use to zero	NR	NR	NR	NR
Zencius et al. (1989a)	SS: Multiple baseline across tx conditions with reversal	III	10 year olds w/severe TBI; normal IQ; impulse control problems & treatment refusal	Contract phase followed by point system (token economy) & response cost for one S	P1: 75 days; P2: 50 days	Staff	Number of therapy sessions attended	NR	Both increased attendance to 100%; all contingency systems appeared effective	S1: maintained at 2 month follow-up; S2: NR	NR	NR	NR
Garcia and Lam (1990)	Multiple base-line across times	III	24 y/o female 1 yr post-severe TBI; serious functional impairments; urinary incontinence; frequent demands of staff	Stimulus control (removal of diapers), timed voidings, praise for remaining dry, over-correction	12 weeks	Staff	Frequency of urinary accidents; frequency of demands for staff attention	NR	Frequency of urinary accidents & demands for staff attention reduced to zero	NR	NR	NR	NR

(continued)

Appendix. Continued.

Reference	Study design	Class of research	Participants	Numbers	Tx Type (CMP, PBIS or combined)	Specifics	Duration	Setting	Provider	Dependent variable	Reliability	Results	Maintenance	Transfer	Social validity
McMillan et al. (1990)	Case Study: Implied AB	IV	38 y/o female; 8 months post-encephalitis; severe cognitive & executive system impairments; Behaviour problems included physical aggression, hypersexual activity, lack of hygiene	1	CMP	Pharmacologic and behavioural interventions; DRL; punishment (restraint, reprimand) for challenging behaviour	aggression: 10 weeks; sexual disinhibition: 27 weeks	Inpatient rehabilitation	Staff	Frequency of violent behaviour, sexual disinhibition, social inappropriateness, & hygiene routine	NR	Aggression reduced from 20/day to zero; hypersexual behaviours reduced from 9/day to less than 1; hygiene required less prompting; post-discharge: social inappropriateness still noted	3 months post-discharge	Effective—reduced aggression; ongoing socially inappropriate behaviour	Discharged to home
O'Reilly et al. (1990)	SS: Changing treatments & multiple baseline across settings	III	P1: 20 y/o female, 8 yrs post-severe TBI; cognitive/memory problems; P2: 37 y/o female, 1 yr post-severe TBI; cognitive/memory problems; P3: 18 y/o male 3 yrs post-severe TBI; mild cognitive problems; P4: 19 y/o male 1 yr post-severe TBI; mild cognitive problems; all were safety risks in living environment	4	Combined	Task analysis & checklist phase; reinforcement for completed items & informational feedback for uncompleted items	5–50 minute sessions weekly, 2–4 weeks	Post-acute residential centre	Staff	Percentage of completed tasks	92–100%	All participants improved in each phase; generalization results varied	All maintained skills at 1 month follow-up; only 2/4 maintained skills at 2 month follow-up	Some transfer noted for noted	Targets directly relevant to living success (accident prevention in the home)
Zencius et al. (1990a)	SS: Multiple treatment settings	III	24 y/r 8 yrs post-severe TBI; frontal & parietal damage; severe cognitive & executive function impairments; weak goal setting, poor social skills, drug abuse, hx of failure in rehabilitation placements;	1	Combined	Phase 1: visual cue followed by making checks for every instance of profanity. Phase 2: eliminate visual cue and add informational feedback	1 month	Residential rehabilitation	Staff	Frequency of profanity in therapy sessions	100%	Profanity reduced to near zero in all treatment sessions and settings	NR	NR	NR
Zencius et al. (1990b)	Case Study: AB	IV	P1: 19 y/o female w/ severe TBI & cognitive & EF impairments; P2: 32 y/o male w/severe TBI & EF impairment; P3: 24 y/o w/severe TBI & cognitive & EF impairment; all w/ inappropriate social behaviour	3	Combined	P1: Scheduled informational feedback sessions; P2: Self-monitoring, private self-stimulation, & role play of positive interactions; P3: Scheduled time to touch appropriately (back rubs)	P1: 3.5 weeks/2 months; P2: 2 weeks; P3: 4 weeks	Residential rehabilitation	Staff	P: Percentage of 30 min intervals w/ appropriate sexual activity; P2: frequency of sexual exhibition; P3: frequency of inappropriate touching	100%	Inappropriate sexual activity decreased to zero or at least acceptable levels while appropriate interaction increased	P2: 4 weeks; NR P1 and P3: none	NR	NR

Author(s)	Study Design	Participant	Intervention	Control	Duration	Staff	Outcome	Notes
Alderman (1991)	SS Study 1: changing treatments; Study 2: AB	24 year old with severe 1 TBI, 6 years post; failed other interventions; memory and executive function impairments; disinhibition, verbal aggression, sexual acting out, incontinence	CMP	No behaviours responded to. Token Economy procedures; incontinence treated with response cost; shouting initially treated with time out; then used satiation training; current pharmacology	Residential rehabilitation	Staff	Frequency of shouting	NR
Alderman et al. (1992)	SS: Reversal	26 year old male 3 years post-severe TBI; cognitive and executive function impairment, verbal aggression, anxiety, reduced frustration tolerance	CMP	Token economy, differential reinforcement of other behaviour, planned ignoring	100 sessions	Therapists	Duration of standing, appropriate posture, rating scale for affect	NR
Peters et al. (1992)	SS: varied designs (reversal); changing treatments	age 21-49; severe TBI; 4 variable cognitive deficits; severe behaviour problems, physical & verbal aggression, elopement, poor hygiene, head banging	CMP	P1: planned ignoring, DRI, time out, medication withdrawal. P2: DRI, planned ignoring, skills training. P3: redirection, feedback cards and meetings, positive activities. P4: Time out, relaxation programme	20, 16, 16, 14 weeks	Staff	Frequency counts challenging behaviours	NR
Silver et al. (1992)	AB Case Study, with mini-reversals	32 month old male 6 months post-gun-shot open TBI; hypothalamic damage with resulting adipisia (refusal to drink); right hemiplegia; no functional speech, irritable to tactile stimulation	Combined	Environmental control (reduced distractions, favoured people), contingent access to preferred foods & social attention, shaping	2 months	Staff & family	Amount of fluid intake by mouth	NR
							Duration of standing quickly reached target and was maintained; duration of appropriate posture: improved but variable; both maintained at 1 yr follow-up; reduction to zero of verbal outbursts	NR
							All improved in targeted areas, but to zero in only two cases; all demonstrated improvements in functional living activities	Discharge to restrictive settings
							Increased fluid consumption; removal of gastrostomy tube	Transfer to home environment
							Maintained at 16 months	Removal of feeding tube and discharge to home

(continued)

Appendix. Continued.

Reference	Study design	Class of research	Participants	Numbers	Tx Type (CMP, PBIS or combined)	Specifics	Duration	Setting	Provider	Dependent variable	Reliability	Results	Maintenance	Transfer	Social validity
Uonoto and Brockway (1992)	Case study: AB	IV	P1: 43 y/o male 2 years 2 post-surgical removal of frontal/temporal glioma; cognitive impairment, verbal & physical aggression; P2: 22 y/o male 3.6 years post-severe TBI bifrontal injury; cognitive & executive function impairments; verbal aggression & self-injury; unawareness/denial	2	PBIS	Cognitive-behavioral self-management training; P1: self-initiated self-time training for families, respectful cuing & environmental simplification; families trained to increase pleasant activities; P2: modify partner communication style, simplify environment, added pleasant events	P1: 10 weeks; P2: 6 weeks	Outpatient	Clinician and family	frequency of angry outbursts, recorded by family members; P2: frequency of angry outbursts & of appropriate social contacts	> 89%	Both reduced frequency of outbursts from baseline to treatment condition; social contacts increased; follow-up demonstrated maintenance of gains	Maintained at 1 and 3 months	Improvement documented in natural environmental settings	Intervention administered by family in natural settings; P2 increased social contacts
Kennedy (1993)	SS: Multiple baseline across subjects	III	20 y/o male; 5 yrs post-severe TBI; severe intellectual impairment; Sz disorder; severe aggressive behaviour; (other 2 S's had Develop. Disability)	1	PBIS	Provide social comments & reduce task demands; gradually re-introduce demands as behaviour improved	40 sessions	Inpatient rehabilitation	Staff	Compliance & correctness of task performance; problem behaviour; social affect	> 89%	Decreased problem behaviour to near zero; improved responses & social affect;	Generally maintained at 4 months	NR	Improvement on Motivation Rating Scale
Slifer et al. (1993)	SS: multiple baseline across subjects; S4: multiple baseline across contexts	III	3 males, 1 female, age 4 to 16, 12-106 days post-ABI; disruptive, verbally & physically aggressive, non-compliant behaviour	4	CMP	DRA, extinction (planned ignoring), response cost, token economy	4-6 weeks	Inpatient rehabilitation	Staff	Compliance with programme rules; frequency of disruptive behaviours (verbal agitation, physical aggression, physical disruption, non-compliance)	NR	Compliance increased while disruptive behaviours decreased (but not to zero)	1-2 months: only 1 of 4 reported no behavioural problems	Need for ongoing behavioural programming after discharge	NR
Davis et al. (1994)	SS: Reversal	III	23 y/o male, 1 yr post-severe TBI, frontal lobe injury; significant cognitive & executive function impairments; verbal & physical aggression	1	Combined	Clear AM routine; written reminders; cues & prompts; social reinforcement; for failure	60 days	Residential rehabilitation	Staff	Frequency of verbal & physical aggression	86%	Aggression reduced to zero (6 month follow-up); including both low & high rates of staff triggers	Maintained 6 months	Transfer to home on weekend passes (wife report)	Reported transfer to home setting
Luiselli (1994)	SS: multiple baseline across instructional sessions	III	8 y/o female w/sterotypical behaviours 2 years post-ABI (anoxic encephalopathy); impulsive, hyperactive, poor organization, compulsive mouthing & grabbing, anxiety disorder, general cognitive impairment	1	PBIS	Non-contingent access to comparable stimulation; subject allowed to choose acceptable functionally equivalent behaviour (chew stick)	14 days	Private special education	Staff	Frequency of object grabbing and mouthing	100%	object grabbing & mouthing reduced to near zero	Improvement maintained at 1 and 6 months	NR	judged by staff and family to be socially valid

Appendix. Continued.

Reference	Study design	Class of research	Participants	Numbers	Tx Type (CMP, PBIS or combined)	Specifics	Duration	Setting	Provider	Dependent variable	Reliability	Results	Maintenance	Transfer	Social validity
Slifer et al. (1995)	SS: Multiple baseline across treatment settings with reversal	III	8 y/o female; 2.5 months post-subarachnoid haemorrhage; significant motor, cognitive, & language impairments; in PTA; severely agitated & labile (aggression, screaming, non-compliance)	1	CMP	Differential positive reinforcement using a token economy system, attention, & praise across settings	60 observations	Inpatient rehabilitation	Staff	Percentage of intervals without target behaviours (aggression, screaming, non-compliance)	>95%	Systematic reduction of target behaviours, first in PT, then OT; in OT, behaviours returned to baseline levels when tx withheld & then back w/reintroduction	NR	NR	NR
Youngson and Alderman (1995)	Case study	IV	34 y/o male 3 yrs post-severe TBI; cognitive & executive function impairments; disinhibited behaviour, inappropriate sexual talk, excessive requests for help around toileting & anxiety. Some issues previously been successfully addressed	1	Combined	Conversation as non-contingent reinforcement, token economy; DRI, TOOTS, systematically increasing exposure to anxiety-producing experiences	28 sessions (7 experimental, 21 treatment)	Residential	Clinicians	Time in the community without verbalizing the need to urinate	NR	Substantial increase in time without requests to urinate; poor correlation between expression of need to urinate & subjective sense of urgency	Improvement at 9 months follow-up	Follow-up was in a new discharge setting	Increase in community activities
Camevale (1996)	Uncontrolled pre-post group	II	7 male, 4 female; TBI; 11 mean age 30.5 (all over 16); mean 10 years post; severity: mild-severe; wide range of injury and pre-injury education; no specification of impairments; significant behaviour problems	11	Combined	Educate caregivers in TBI & intervention strategies; antecedent control and reinforcement procedures; various settings	1 year	Family home	Caregiver trained by clinicians	Target behaviours selected by caregivers & Ss (e.g. verbal & physical aggression; lack of productive activity; self-injury)	Families trained	All reported reduction in target behaviours and/or increased positive behaviours; 82% change from onset of intervention to phase out	Maintained through 12 months	NR	Families reported programme practical & helpful
Slifer et al. (1996)	SS: two subjects: AB; three subjects: multiple baseline across subjects	III	4 males, 2 females, 8-16 y/o, recent onset TBI, all in PTA; 28-77 days post; problem behaviours included disruption, inattention, elopement, crying, non-compliance with treatment	6	CMP	DRA, token economy with tangible reinforcers, planned ignoring, response cost	6-20 observations	Inpatient rehabilitation	Trained therapists	Percentage of occurrence of target behaviours or% of target behaviours where target behaviour occurred	90%	Mean occurrence of target behaviours decreased for all children; reduced to zero in 4 cases	NR	NR	Increased participation

Treadwell and Page (1996)	Case study: AB	IV	P1: 37 y/o male 13 years post-severe TBI; P2: 3.6 y/o male with brain injury post-meningitis; both: severe behaviour problems including aggression, self-injury, property destruction & non-compliance	2	Combined	P1: antecedent prompts, behavioural momentum, extinction (planned ignoring). P2: functional communication training, extinction (planned ignoring)	P1: 15 days; P2: 12 days	Residential care	Unclear	Percentage of intervals without target behaviours and level of compliance	P1: decreased frequency of target behaviours to near zero, increasing compliance; discharged to community re-entry programme. P2: used words rather than negative behaviour for access communication, returned to home & educational placement	NR	NR	NR
Alderman and Knight (1997)	SS: Multiple baseline across behaviors and reversal	III	P1. 58 y/o male, 2 yrs post-severe TBI; memory & executive function deficits; anxiety; physical & verbal aggression; P2. 35 y/o female, 3 yrs post-subarachnoid haemorrhage; impaired cognition & executive functions; verbal & physical aggression; verbal abuse; P3. 33 y/o male, 7 yrs post-severe TBI; memory & executive function deficits; verbal aggression	3	CMP	P1, 2, & 3: TE; DRU; verbal & written cues; informational feedback	P1: 7 weeks; P2: 8 weeks; P3: 8 weeks	Residential rehabilitation	Staff	Frequency of target behaviours during AM hygiene routine: throwing, shouting, sexual comments, swearing, verbal abuse	Target behaviours reduced to acceptable levels; increase in independence & in expectations	P1. 1, 4, 12, NR P2. 5 months; P3. NR	P1. Greater independence; Discharge less restrictive environment	
Manchester et al. (1997b)	Case Study: AB	IV	17 y/o male, 8 months post-severe TBI, bilateral frontal lobe injury; executive function impairment w/associated severe behaviour problems, physical & verbal aggression, non-compliance, stealing	1	CMP	Token economy; gradually increasing expectations	13 weeks	Acute rehabilitation	Staff	Frequency of absconding	Absconding reduced from 20 times in 11 days to zero	NR	NR	Intervention judged by nurses to be effective and doable
Manchester et al. (1997a)	Case Study: Implied AB	IV	25 y/o male 2 yrs post-severe TBI, bilateral frontal lobe injury; cognitive & executive system impairment; severe behaviour problems, verbal & physical aggression	1	CMP	Token economy (DRO), extinction (TOOTS, response cost);	31-44 weeks (11 month admission)	Cottage on hospital grounds	Staff	Frequency of aggression, shouting, bathing	Frequency of aggression & shouting reduced to zero; bathing increased from rare to daily; 10 month follow-up: no aggression & increased community integration	Maintained at 10 months	To discharge setting	Increase community participation

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Appendix. Continued.

Reference	Study design	Class of research	Participants	Numbers	Tx Type (CMP, PBIS or combined)	Specifics	Duration	Setting	Provider	Dependent variable	Reliability	Results	Maintenance	Transfer	Social validity
Persel et al. (1997)	SS: Reversal	III	40 y/o male; 13 severe post-TBI; severe cognitive deficits; Behaviour problems, physical aggression & self-injurious behaviour	1	Combined	Combination of scheduled non-contingent reinforcement (social conversation) & contingent restraint	13 weeks	Long-term care facility	Staff	Frequency of aggression & self-injurious behaviour	97%	Both physical aggression & self-injury reduced to low levels & increased during reversal phases	1 month	NR	NCR easy for staff
Slifer et al. (1997)	SS: multiple base-line across subjects	III	Females aged 16-17, 13-65 days post-severe TBI; emerged from PTA within the study; all with frontal lobe injury & associated behavioural dysregulation: verbal & physical aggression, grabbing, throwing, refusal to participate in therapy	3	Combined	Stage 1: Compliance training w/minimal demands and ample antecedent supports. Stage 2: Compliance training during normal therapy routine; contingencies included: reinforcement, planned ignoring, redirection. One S had pharmacologic Tx	50, 25, 70 days	Inpatient rehabilitation	Staff	Percentage of tx sessions attended; percentage of intervals w/target behaviour; level of demands presented	89% in prior study	% of therapies attended increased to 100%; disruptive behaviours reduced to near zero; demands systematically increased	NR	NR	NR
Aeschman and Imes (1999)	SS: multiple base-line across subjects	III	Five young adult males (age 20-30): 3 severe TBI, 1: moderate TBI, 1: brain stem injury. All long-term post (1.5-12 years); mild IQ impairment; verbal and physical aggression; other impulsive behaviours	5	PBIS	Stress inoculation training (relaxation, self-instruction, coping skills);	10 Weeks	Residential rehabilitation	Clinicians & staff	Impulsive aggression (verbal, gestural, physical), role play probes, counsellor questionnaire	85-100%	Slight ('not substantial') reduction in impulsive behaviours during treatment; role play probes improved, but judged to lack validity	15 weeks of F-U data	NR	Counsellors judged tx moderately socially valid

Alderman et al. (1999)	Case studies: AB IV	P1, 34 y/o male 4 3 months post-severe TBI; multifocal injury including frontal damage; physical, cognitive, & executive function impairments; physically aggressive, sexually disinhibited, non-compliant. P2, 45 y/o female 3 yrs post-subarachnoid haemorrhage; severe cognitive & executive function impairments; physically aggressive. P3, 40 y/o male 2 years post-oxic brain injury; severe cognitive & executive function impairments; physically aggressive.	Combined	P1: environmental structuring and clear routine to reduce provocation; positive reinforcement and time out; P2. Token economy, time out, pharmacology. P3. Errorless learning, visual prompts, reduced expectations, pharmacology	P1, 5 weeks; P2, 6 weeks; P3, 60 weeks	Residential rehabilitation	Staff	P1&2: frequency and severity of aggression; P3. Frequency of aggression	Established in other publication	SP. Reduced to near zero over 4 weeks; zero a 4 month follow-up. P2. Frequency slightly reduced; intensity not reduced. P3. Minimal results until expectations were dramatically reduced	P1. Maintained 17 weeks; P2, 16 weeks, 30 weeks; P3. None	NR	Intervention made participation in rehabilitation possible
Peck et al. (1999)	SS: Reversal with fading	15 y/o male; 1 year after acquired Sz disorder; corpus callosum at age 11; moderate cognitive deficits; stereotypic behaviours, hitting objects & clapping hands for sensory effects	CMP	Systematic use of interruption/redirection motor commands contingent on stereotypic behaviours; social reinforcement	15 weeks	Residential school	Staff	Frequency of stereotypic motor behaviours (e.g. tableslapping, hand clapping)	98%	Target behaviors to acceptably low levels	NR	NR	Able to benefit from educational programme
Rothwell et al. (1999)	Case Study: AB IV	TBI, age 31 and 20 months post; cognitive impairments; problem behaviours, physical aggression & property damage	Combined	Skills training: general, functionally equivalent, related skills; choice and control, anxiety management training, reactive strategies (extinction, stimulus change)	P1: 3 months; P2: 17 weeks	Residential rehabilitation	Staff	P1: frequency of physical aggression; P2: number of days/week target behaviour was present	NR	P1: Behaviour systematically reduced to zero; P2: frequency reduced to zero; returned to home with no reported problems	P1: 20 months, 1 year; P2: transfer to home setting	Both improved quality of life; P2 discharged to home	

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Appendix. Continued.

Reference	Study design	Class of research	Participants	Numbers	Tx Type (CMP, PBIS or combined)	Specifics	Duration	Setting	Provider	Dependent variable	Reliability	Results	Maintenance	Transfer	Social validity	
Schlund and Pace (1999)	Case study: multiple baseline across subjects	III	TBI within previous 9 years, gender, NR; ages 27, 33, 48; mild cognitive impairments; depression; behaviour problems: P1: pseudoseizures, P2: inappropriate sexual behaviour, P3: non-compliance	9	Combined	Weekly feedback sessions added to existing strategy trainings, which included: P1: antecedent staff assistance with self-expression, P2: antecedent verbal prompting, P3: antecedent review of programme rules & procedures	10, 8, 56 weeks	Medical day programme	Staff	Frequency of targeted challenging behaviours	NR	All target behaviours reduced in frequency	NR	NR	NR	
Teichner et al. (1999)	Case study	IV	13 y/o female 10 months post-severe TBI; prior learning disabilities; cognitive & executive function impairments, behaviour problems: physical & verbal aggression, property destruction, non-compliance, avoidance of home & school	1	Combined	Token economy reinforcement system, parent & teacher training, self-management training, environmental & task control to prevent challenging behaviour, social skills training (modeling and mass rehearsals)	45 1-hour sessions over 11 months	Outpatient, home, school	Specialists, parents, school personnel	Child Behaviour Checklist; Personality Inventory for Children, Minnesota Multiphasic Personality Inventory-Adolescent	NR	Improvements pre vs post on Child Behaviour Checklist; parent report: no aggression & increased social activity after 4 months	Maintained at 8 month follow-up; successful at home and school	Programme implemented at home and school	Programme doable by parents and educators	
Hartnedy and Mozzoni (2000)	SS: Multiple baseline reversal and across subjects	III	P1: 6 y/o female: 4 months post-severe TBI; severe cognitive, EF, communication impairment P2: 16 y/o female: 6 weeks post-severe TBI; significant cognitive deficits;	2	Combined	Reduce environmental & social stimulation; reduce eating demands; prescribed minimal responses to refusal or off-task behaviour	24 & 20 days	Inpatient rehabilitation	Staff	% of meal eaten; weight gain; removal of feeding tube; tolerance of other children at meal time	Mean 97-100%	Tubes removed, gained weight, ate adequate% of meals under Tx conditions, & tolerated other children	NR	NR	NR	Weight gain; removal of tubes
Hegel and Ferguson (2000)	SS Multiple baseline across settings	III	Both refused to eat post-severe TBI; severe physical impairment; severe physical aggression	1	CMP	DRO: Differential reinforcement of other behaviour, with increasing time expectations; reinforcement was with client selected preferred activities	50 days	Long-term inpatient	Staff	Frequency of aggressive behaviours	NR	Aggressive behaviours reduced to near zero	Maintained at 1 month	No transfer from setting to setting	NR	

Meidd and Tate (2000)	Between & w/in group; blinded, matched randomized, crossover design	I	8	PBIS	Experimental group: cognitive-behavioural treatment; stress inoculation training to prevent or control anger responses, TBI education, self-awareness training, anger management strategies. Control group: anger monitoring	1 individual session/ week for 5-8 weeks (average 6 sessions)	NR	Staff	Researcher, classroom staff	Anger: Trait-Anger Expression Scales; Anger Generalization; Self-Esteem Inventory, hospital Anxiety & Depression Scale, Patient Competency Rating Scale; Neuropsychological tests	Anger: both groups decreased pre vs post—experimental group greater	Maintenance at 2 months	Minimal for self-esteem, anxiety, depression, self-awareness	Participants judged programme to be beneficial
Meidd and Tate (2000)														
Selznick and Savage (2000)	SS: multiple baseline across subjects with alternating treatments	III	3	PBIS	1. On tape recorded cue, self-record variables; 2. Choose self-monitoring cue, 3. Phase out cues	25, 20, 20 weeks	NR	Residential school classroom staff	Researcher, classroom staff	% of on-task behaviour; % of problems correct; duration of task engagement	decreased pre vs post—experimental group greater	at 2 months	self-esteem, anxiety, depression, self-awareness	NR
Yodi et al. (2000)	Case study: AB	IV	1	Combined	Organized, meaningful routine; meaningful setting for therapies; non-contingent Rf; token economy; positive reinforcement; extinction (planned ignoring); problem-solving sessions	3.5 months	NR	Residential behaviour programme	Staff	Frequency of elopement, medication refusals, verbal aggression, physical aggression	Decrease in frequency of all target behaviours, but variable	NR	NR	NR
Watson et al. (2001)	Case study: AB	IV	1	CMP	DRR (later switched to token economy); extinction; withdrawal of attention following negative behaviour (TOOTS); graduated increase of expectations	100 weeks	NR	Long-term residential rehabilitation	Staff	Frequency of aggressive behaviours	Aggressive behaviours reduced to zero	Low rates maintained after discharge to group home	Treatment continued in new setting	Tx enabled less restrictive setting & increased community activities

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Appendix. Continued.

Reference	Study design	Class of research	Participants	Numbers	Tx Type (CMP, PBIS or combined)	Specifics	Duration	Setting	Provider	Dependent variable	Reliability	Results	Maintenance	Transfer	Social validity
Guerico and McMorrow (2002)	Case study: AB	IV	20 y/o male (time post-NR); severe TBI; severe cognitive & communication impairments; intense behavioural outbursts: sexually inappropriate behaviour, physical aggression, property destruction	1	PBIS	Placement in less restrictive environments; greater opportunity for normal socialization; provision of appropriate sexual outlets; positive attention for socially appropriate behaviour	4 months	Post-acute residential centre	Staff	Frequency of physical aggression, property destruction, sexually inappropriate behaviour	NR	Reduction to zero of all targeted negative behaviours	Anecdotal	To home & community settings	Successful discharge to home
Knight et al. (2002)	SS: reversal and changing treatments designs	III	P1: 19 y/o male; P2: 44 y/o female; P3: 53 y/o male; severe TBI or haemorrhagic stroke; 5-13 years post; executive function impairment & associated severe behaviour problems (e.g. aggression, sexual disinhibition)	3	CMP	DRL and self-monitoring training	P1: 36 weeks; P2: 12 weeks; P3: 8 weeks	Residential rehabilitation	Staff	Frequency of targeted challenging behaviours	NR	All target behaviours reduced; reduction not necessarily related to self-awareness (self-monitoring may not be necessary for reinforcement learning)	P1: 2 years; P2: NR; P3: 3 months	NR	NR
Alderman (2003)	Case studies: AB	IV	P1: Adult male with severe TBI; time post-NR; memory and executive function impairments; severe verbal and physical aggression; post-acute rehabilitation. P2: Adult male 4 years post-severe TBI; memory and executive function impairments, physical and verbal aggression	2	Combined	P1. Monitoring treatment, cognitive appraisal, coping strategies, environmental compensations, systematically increasing demands. P2. Consistent routine, increase staff support, verbal mediation, differential reinforcement, systematic increase in expectation	P1: 22 weeks; P2: 20 weeks	Residential rehabilitation	Staff	P1. Frequency of aggression, P2. Frequency of aggression, shouting	NR	P1. Aggression reduced to zero. P2. Decrease in both shouting and aggression	P1: none; P2: maintained 3 years	NR	NR
Dixon et al. (2003)	SS: Alternating tx	III	21 y/o male w/severe TBI; time post: NR; minimal description; severe impairment; history of refusing PT	1	Combined	Training to choose the larger delayed reinforcer that also required hand opening vs immediate small reinforcer with no hand opening; gradually increase hand opening time	120 session	Residential rehabilitation	Staff	Hand opening & self-control (shift to choice of larger delayed reinforcer over smaller immediate reinforcer)	93-100%	Increasing choice of delayed reinforcer, i.e. requirement for hand opening, improved self-regulation of behaviour	NR	NR	NR

Ebanks and Fisher (2003)	SS: Reversal	III	Male age 19; time post: NR; post-severe TBI; intellectual impairment & PDD; frequent aggression against people & property, self-injurious behaviour	1	PBIS	(1) Reduce task difficulty by interspersing easy w/ challenging tasks; (2) substitute antecedent prompts ('precorrections') for errors followed by corrective feedback	20 sessions	Inpatient Tx room	NR	Escape-motivated aggressive & self-injurious behaviours	> 95%	The two antecedent control interventions reduced frequent aggressive & self-injurious behaviours to zero	NR	NR	NR
Feeney and Yivisaker (2003)	SS: Reversal	III	6 y/o female 1 yr post-severe TBI; both w/frontal lobe involvement; cognitive & executive function impairment; significant & escalating externalizing behaviour problems (verbal and physical aggression)	2	PBIS	Daily routine (negotiation & choice), before difficult tasks, errorless learnings, communication training (staff & children), graphic organizers for complex tasks, daily Goal-Plan-Do-Review routine	3 weeks	Classroom	School staff, including aides	Frequency & intensity (Aberrant Behaviour Checklist) of aggressive behaviours, amount of work completed; staff perception of student outcome & intervention implementation	> 90%	Frequency & intensity of challenging behaviours decreased; amount of work increased; at 1 and 8 year follow-up, both doing well with minimal supports	Maintained at 1 & 8 yrs	To new classroom interventions judged to be useful	
Gardner et al. (2003)	Case study, longitudinal design	IV	P1: 12 y/o male > 5 yrs post-severe TBI; P2: 13 y/o male > 5 yrs post-severe TBI; both expelled from community schools because of severe behaviour problems, a history of inpatient care in locked psychiatric units, a history of failed tx attempts, & variety of learning-psychiatric diagnoses	2	PBIS	5 phases of PBIS & pharmacologic tx; PBIS procedures: negotiation w/Ss, functional communication training, several antecedent management strategies; supports systematically reduced & community activities systematically increased	3.5 & 2.5 yrs	Residential school	Staff	Challenging behaviours, staff hours of direct support, drug doses, Qualitative data: family involvement, peer relationships, vocational status, community access, self-help skills	> 85%	Frequency of challenging behaviours reduced; staff supports systematically reduced; alternative communication responses increased; reduction in medication and staffing supports; increase in completion of school & household tasks; improved academic performance	Maintained 2.5-3.5 yrs	Systematic increase in community activities	Improved social relationships, community involvement, educational success, family inter-action
Willis and LaVigna (2003)	Case study: implied AB design	IV	20 y/o male, 3 yrs post-severe TBI bilateral frontal lobe injury; cognitive & executive system impairments; behaviour problems: physical aggression, property destruction, elopement, inappropriate interaction w/ females	1	PBIS	Services delivered in the home, 'mentor model' (i.e. support staff as 'buddy'), ample antecedent suggestions & modeling, staff scripts, relaxation training, redirection w/ favoured Bible verses	10 years	Home & community	Staff, family, researcher	Frequency of physical aggression, property destruction, elopement, verbal aggression, inappropriate interactions w/ women; data collected in 3 month blocks over 10 years	NR	All target behaviours decreased from baseline; elimination of property destruction; aggression continued to escalate w/medication & staff changes	NR	NR	NR
Bezeau et al. (2004)	Case study	IV	31 y/o male 7 years post-severe TBI; frontal, multi-focal damage, diffuse axonal injury; cognitively rigid & impulsive; co-existing depressive psychosis; severe sexually intrusive behaviour	1	PBIS	Training in self-regulation at beginning of behaviour chain; 'Circles' programme to acquire skills for relating to women; verbal self-cuing; assigned male role models; psychopharmacology	2 months	Residential rehabilitation	Staff	Frequency of sexually intrusive behaviours	NR	Absentism reduced to acceptable levels; disruption reduced to zero, used memory aids	Maintained 16 months	'Functions well' in group home	To group home in home comm unity

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Appendix. Continued.

Reference	Study design	Class of research	Participants	Numbers	Tx Type (CMP, PBIS or combined)	Specifics	Duration	Setting	Provider	Dependent variable	Reliability	Results	Maintenance	Transfer	Social validity
Fyffe et al. (2004)	SS: Reversal	III	Male age 9; post-TBI; motor impairment; limited speech; aggressive & inappropriate sexual behaviour (ISB; e.g. touching)	1	Combined	Functional communication training (to replace ISB), including reinforcement of positive alternatives, & extinction (no attention to ISB)	40 sessions	Inpatient rehabilitation	NR	Frequency of ISB vs appropriate communication	> 89%	ISB reduced from 6.7 to 0.4 min; use of appropriate communication increased from 0 to 1.5 times/min., & was then thinned	NR	NR	NR
Morram et al. (2004)	SS: Multiple baseline across subjects	III	P1: 8 y/o male, post-hydrocephalus, time post: NR; ODD, mild cognitive impairment, verbal aggression; P2: 6 y/o male, severe TBI bifrontal lesions; time post: NR; ADHD, oppositional behaviour; P3: 14 y/o male, 4 yrs post-viral encephalopathy, seizures, IQ 50, oppositional behaviour	3	Combined	Regular review of clear behavioural rules; token economy (positive reinforcement and response cost); systematic fading	20-30 sessions	After-school tx in rehabilitation facility	Staff	Behaviour Assessment Scale for Children; Student Observation System (school and home); Consumer Satisfaction Index for children; Teacher Acceptability Scale for counsellors	91-100%	Systematic decrease in disruptive behaviours with Tx (average 69%)	Maintained 7-10 sessions after treatment ended	NR	Judged to be satisfactory by children and acceptable by counsellors
Feeney and Yvisaker (2006)	SS: Reversal	III	P1: 6 y/o male 2 yrs post-severe TBI; P2: 7 y/o male 3 yrs post-severe TBI; both with frontal lobe involvement; cognitive & executive function impairment; significant & escalating externalizing behaviour problems (physical and verbal aggression)	2	PBIS	Daily routine (negotiation & choice), positive momentum before difficult tasks, errorless learning, communication training (staff & children), graphic organizers for complex tasks, daily Goal-Plan-Do-Review routine	3 weeks	Classroom	School staff, including aides	Frequency & intensity of aggressive behaviours, amount of work completed; staff perception of student outcome & intervention implementation	> 90%	Frequency and intensity of aggressive behaviours reduced; amount of work completed increased; intervention judged to be doable by staff	Maintained at 1 yr	P1: NR; P2: improvements transferred to new class room	Socially valid; interventions judged to be useful

Wade et al. (2006)	RCT	I	Average 9 months post-moderate-severe TBI (16 experimental: 10 male, 16 control: 11 male); age 5-16; mean age: 11; specific behaviour problems not reported	32	PBIS	Individualized family problem-solving, focus on antecedent cognitive supports (to increase success in tasks), proactive behavioural supports, & positive communication	6 months: 7 core sessions; up to 4 additional	Parent training in clinic or home; child support at home	Clinician trained parents to deliver supports	Child Behaviour Checklist, Brief Symptom Inventory, Conflict Behaviour Questionnaire, Satisfaction Survey	As per manual	Control group: reduction of internalizing symptoms (depression, anxiety, withdrawal); no effect on parental distress measure (ceiling effect); all parents reported improved parent-child relationships & improved knowledge & skill	NR	Intervention delivered in natural contexts	Parents and children judged the programme to be extremely helpful and easy to use
Feeney and Yivisaker (2007 in press)	SS: Reversal	III	First graders children w/preschool TBI, frontal lobe involvement; cognitive impairment (organization & learning problems with normal IQ), significant & escalating externalizing behaviour problems (aggression)	2	PBIS	Daily routine (negotiation & choice), positive momentum before difficult tasks, errorless learning, communication training (staff & children), graphic organizers for complex tasks, daily Goal-Plan-Do-Review routine	3 weeks experiment; supports maintained	Community school	School staff, including aides	Frequency & intensity (Aberrant Behaviour Checklist) of aggressive behaviours, amount of work completed; staff perception of student outcome & intervention implementation	> 90%	Frequency & intensity of aggressive behaviours reduced; amount of work increased; intervention judged to be doable by staff	To new classroom	Maintained at 1 yr Judged to be socially valid; interventions judged to be useful	

CMP: Contingency Management Procedures, PBIS: Positive behaviour interventions and supports/antecedent control focus, SS: Single-subject experiment, RCT: Randomized controlled trial, NR: Information not reported in the publication, TOOTS: Time out on the spot, DRO: Differential reinforcement of other behaviors, DRI: Differential reinforcement of incompatible behaviours, DRA: Differential reinforcement of appropriate behaviours, DRL: Differential reinforcement of low rates of behaviour.

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