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APPLIED BEHAVIOR ANALYSIS IN ACQUIRED BRAIN INJURY REHABILITATION: A META-ANALYSIS OF SINGLE-CASE DESIGN INTERVENTION RESEARCH

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The purpose of this meta-analysis was to complete a systematic evidence-based review of published behavioral treatment studies employing single-case designs with both children and adults with acquired brain injury. Peer-reviewed journals were searched using PsycINFO, Medline, and ERIC databases with combinations of terms such as brain injury, behavior disorder, behavior therapy, behavior modification, behavior analysis, and verbal behavior. A total of 112 acquisition and reduction studies met the established inclusion criteria. The data extracted from each study included specific details about the participants, target responses, intervention characteristics, use of functional assessment, and outcome characteristics. A data extraction software program was also used to extract data from graphs to calculate percentage of nonoverlapping data as an effect size. The studies were then evaluated along several dimensions from multiple evidence-based practice frameworks. Collectively, interventions targeted a wide range of behaviors for acquisition and reduction, but only five interventions were classified as *well established* according to the American Psychological Association Division 12 criteria. Furthermore, methodology of the identified studies was found to be relatively poor. A variety of methodological concerns are discussed. Copyright © 2014 John Wiley & Sons, Ltd.

Each year in the USA, at least 1.7 million individuals sustain a traumatic brain injury (TBI; Faul, Xu, Wald, & Coronado, 2010). When comparing the rate of long-term disability prevalence of Americans, TBI ranks as the third leading cause behind major depressive disorders (18.8 million) and intellectual disabilities (6.2–7.5 million; Lash, 2007). However, when the prevalence rates of TBI and stroke are combined, acquired brain injury (ABI; i.e., a more comprehensive definition that includes brain injuries resulting from an internal insult to the brain) becomes the second leading cause of disability in the USA (Lash, 2007).

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Sustaining an ABI can result in wide-ranging consequences, both in areas of functioning (e.g., sensorimotor, cognitive, behavioral) and level of severity, which may be temporary or persist throughout an individual's lifetime (Lash, 2007). These consequences following an ABI can present very unique challenges across the continuum of care, particularly for consequences that are less clearly observable (e.g., simple seizures, migraines). The continuum of care for individuals with ABI experiencing cognitive and behavioral consequences includes a variety of settings as rehabilitation can begin from the onset of the injury and may extend throughout an individual's lifetime (Lash, 2007). Systems of care for individuals with ABI may include hospital-based settings (e.g., acute hospital care), subacute settings (e.g., skilled nursing facilities), post-acute rehabilitation sites, and outpatient settings (e.g., supported living).

Although entering into the continuum of care is crucial to reduce the likelihood of ABI-related disability, the extreme cost of receiving rehabilitation services has led to a continuing decline in the length of stay in rehabilitation programs. For example, Lenmkuhl, Hall, Mann, and Gordon (1993) found that the overall mean length of stay in acute care was 27 days, and the overall mean length of stay in rehabilitation was 48 days. Overall, the cost and limited time in neurorehabilitation settings has created a demand that therapists optimize their time by using as many effective and efficient intervention strategies as possible in order to achieve discharge goals and successfully reintegrate individuals with ABI back into community settings (Lewin, 1992).

The substantial need for effective and efficient interventions for cognitive and behavioral consequences in neurorehabilitation presents behavior analysts with the opportunity to demonstrate the utility of applied behavior analysis (ABA) in a prevalent and growing population base (LeBlanc, Heinicke, & Baker, 2013). In the past two decades, several chapters, handbooks, and special issues of behavioral journals have been published on the use of ABA in ABI rehabilitation (e.g., Jacobs, 2000; Mozzoni, 2000, 2005; Pace & Nau, 1993). Mozzoni (2008) articulated the value of ABA's emphasis on both operational definitions and single-case designs (SCDs) to evaluate rehabilitation outcomes and ABA's flexibility to be incorporated with other philosophical orientations that are often found in a multi-disciplinary team. In addition, numerous SCD studies on ABA rehabilitation methods for ABI have been published within and outside of behavior analytic journals. To date, there have been four systematic reviews of these SCD studies. These reviews are discussed next.

PRIOR REVIEWS OF APPLIED BEHAVIOR ANALYSIS APPLICATIONS IN ACQUIRED BRAIN INJURY

Gurdin, Huber, and Cochran (2005) reviewed the effects of behavioral interventions in 20 studies conducted with participants under the age of 22 years who were

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receiving services from pediatric care providers. Studies were included in this review if the following criteria were met: (i) if an experimental design was used; (ii) if the independent variable was behavioral in nature; and (iii) if operational definitions were included. Gurdin et al. found that antecedent intervention packages were most commonly used and included components such as task interspersal, prompting, and demand fading. The remaining studies were categorized as occurring in rehabilitation or therapeutic environments (e.g., physical therapy). The authors found that variations of differential reinforcement procedures were most commonly employed in the behavior-reduction studies, and shaping, fluency training, and behavioral contracts were employed in the skill acquisition studies. Overall, these data-based studies supported the use of behavioral interventions in either reducing problem behavior or increasing adaptive skills in children and adolescents with brain injuries across multiple treatment settings. Unfortunately, the authors only provided a cursory description of their search strategy that would not easily be replicable, and the search was seemingly not exhaustive in nature, reducing the impact of the authors' conclusions.

Another evidence-based review evaluated pediatric cognitive and behavioral interventions for ABI (Laatsch et al., 2007). The purpose of this review was to update and broaden a previous review by Limond and Leek (2005) that evaluated pediatric cognitive interventions for ABI and found no conclusive positive evidence for cognitive rehabilitation. The authors classified the studies and subsequently made treatment recommendations based on the *Clinical Practice Guideline Process Manual* published by the American Academy of Neurology (Edlund, Gronseth, So, & Franklin, 2004). The authors concluded that even though the number of pediatric studies was limited (i.e., only 28 studies were included in the review), practice guidelines for the comprehensive and attention/memory domains could be made. However, no guidelines or practice options could be developed from the interventions in the behavioral domain as only eight studies were identified and were classified as either Class III or IV according to the level of evidence classification system used by the authors.[1] It is worth noting that the limited number of pediatric studies in the behavioral domain may be due to the authors' choice of key terms used in the initial search of the literature. The terms 'behavior therapy', 'behavioral therapy', and 'cognitive-behavioral therapy' were used; however, including additional search terms relevant to the treatment

[1] Studies classified as Class I, II, and II were randomized controlled trials with Class I and II studies requiring the use of a matched group cohort. Class I studies also required the use of 'masked' outcome assessment, clearly defined primary outcomes, exclusion/inclusion criteria, adequate accounting of dropouts, and sufficient matching of subjects across experimental and control groups. If any of the aforementioned criteria were not met, the study was classified as Class II. Class III studies involved well-defined natural history controls or participants serving as their own controls, as well as an independent outcome assessment derived from an objective outcome measure. Class IV studies did not include a control group and were either individual case studies or a clinical case series.

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of behavioral targets such as 'behavior modification' and 'behavior analysis' may have identified a larger number of studies employing behavioral interventions.

In a third literature review, Ylvisaker et al. (2007) identified 65 studies for children and adults with behavior disorders following TBI, approximately half of which used SCDs. Nine of the studies targeted increases in target responses, 34 targeted decreases, and 15 targeted both. These studies were categorized from an intervention framework as primarily traditional contingency management ($n = 26$), primarily positive behavior interventions and supports ($n = 17$), or a relatively equal combination of the two ($n = 22$). Overall, the authors found that at least one target behavior was improved in each study, and most reductive procedures were socially significant as evidenced by 44 of the 65 studies reporting positive findings with social validity measures. The authors adapted a level of evidence classification system found in other health-related reviews (e.g., Cicerone et al., 2005) that incorporated SCDs. Ylvisaker et al. concluded that behavioral interventions be considered for both acute and post-acute stages of recovery for children and adults with behavior problems after a TBI and that specific behavioral interventions grouped under the headings of contingency management procedures or positive behavior supports be considered evidence-based treatment options. Although there seems to be merit in this review, the authors' decision to separate behavioral interventions into categories involving traditional contingency management and positive behavioral supports has been criticized. Slifer and Amari (2009) state that this distinction is not parsimonious nor helpful to the behavioral community because descriptive terms arising out of the field of ABA can be found in both categories; therefore, Slifer and Amari suggest using a taxonomy involving behavior principles or descriptive methodologies when reviewing and analyzing behavioral interventions.

Lastly, Cattelani, Zettin, and Zoccolotti (2010) expanded on the review by Ylvisaker et al. (2007) by reviewing the rehabilitation treatment literature for adults (i.e., individuals 16 years of age and older) with ABI to include other intervention options outside of ABA. The authors categorized a total of 63 studies as fitting a behavior-analytic, cognitive-behavioral, or comprehensive-holistic intervention approach. The authors classified the studies using levels of evidence determined by referring to the neurological management guidelines of the European Federation of Neurological Societies (Hughes, Barnes, Baron, & Brainin, 2001) and rating systems used in previous reviews on cognitive rehabilitation. The authors concluded that comprehensive-holistic rehabilitation programs should be considered a standard treatment, whereas ABA and cognitive-behavioral therapy should be only considered evidence-based treatment options for adults with psychosocial and behavioral problems following an ABI.

First, some reviews only included a limited population, and the limitations of the aforementioned reviews of the ABA intervention literature for individuals with

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ABI should be noted. For example, only the review by Ylvisaker and colleagues included studies conducted with both children and adults; however, that review only included studies conducted with individuals with TBI and not ABI (i.e., the more comprehensive definition of brain injury). Second, the levels of evidence classification systems used in the previous reviews are not commonly used for psychological research. The Clinical Psychology Division (i.e., Division 12) of the American Psychological Association (APA) has published evidence-based practice standards (Chambless & Ollendick, 2001); however, these standards were not employed in the aforementioned reviews. The use of APA Division 12 standards is important because psychology is one discipline (other than education) that is heavily involved in the intervention of individuals with developmental disabilities and brain injury (Newsome & Hovanitz, 2005). In addition, psychology is experiencing pressure toward evidence-based treatment from public and private health plans. Third, the categorization frameworks used in the previous reviews were not particularly helpful for describing and categorizing behavioral interventions in ABI. Finally, none of the previous reviews conducted in this specific literature has calculated effect sizes for the SCD studies that were identified.

RATIONALE FOR THE PRESENT REVIEW

The purpose of the present meta-analysis was to provide a synthesis of the existing behavioral intervention studies with individuals with an ABI diagnosis and expanded on previous review papers in a number of ways. First, the reported characteristics of participants, interventions, outcomes, and the methodology used in both skill-acquisition and behavioral-reduction studies were examined with both children and adults with an ABI diagnosis. Second, the use of functional assessment was coded for reductive procedures. Third, behavioral interventions were classified in a more detailed manner. Fourth, quantitative measurements of intervention effectiveness (i.e., calculations of effect sizes) were included using a well-defined coding system. Finally, behavioral interventions were classified using two existing evidence-based practice frameworks.

METHOD

Article Identification

A search of the literature was conducted to identify articles published in English in which interventions using a behavior-analytic approach were applied

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to either increase skills or decrease problem behavior in individuals diagnosed with an ABI. The PsycINFO, ERIC, and Medline databases were searched using the following keyword combinations: head injury or brain injury and behavior disorder, behavior therapy, behavior modification, behavior management, behavioral therapy, behavior analysis, ABA, or verbal behavior. In addition, manual searches of the tables of contents were conducted for the following behavior analytic and brain injury journals: *Journal of Applied Behavior Analysis*, *Behavior Modification*, *Behavioral Interventions*, *Journal of Head Trauma Rehabilitation*, and *Brain Injury*.

Ancestral searches of recent literature reviews of behavioral interventions in brain injury rehabilitation were also conducted (i.e., Cattelani et al., 2010; Gurdin et al., 2005; Laatsch et al., 2007; Ylvisaker et al., 2007). From these initial searches, 1410 articles were identified as of May 2012. Articles were excluded for the following reasons: (i) if they employed a group design to evaluate the intervention(s); (ii) if they were theoretical articles or descriptions of intervention approaches or programs; (iii) if they were review articles; (iv) if they were case studies without sufficient quantitative data (i.e., repeated measures with at least two data points in both the baseline and intervention conditions); (v) if they were studies described in book chapters (i.e., not peer-reviewed); (vi) if they did not include sufficient clarity in graphs to permit the calculation of effect sizes, or (vii) if they included participants with ABI who had a prior identified congenital diagnosis. One hundred and twelve articles remained for coding (Figure 1).

Data Coding

The unit of analysis for this review was an individual participant's intervention evaluation rather than the study as a whole. The participant-level unit of analysis was chosen because the focus of the current review was SCD research in which the participant serves as his or her own control. All of the studies reviewed in the current analysis were coded using the following categories per participant evaluation.

Participant Characteristics

The following information was recorded for each participant: pseudonym or number, age, gender, time since injury, length of coma, injury severity (i.e., mild, moderate, severe), coma score report (i.e., Glasgow score, Rancho Los Amigo score), type of injury (i.e., TBI or ABI), cause of injury (e.g., fall, motor vehicle accident, anoxia), a description of the injury (e.g., subdural hematoma), if the head injury was classified

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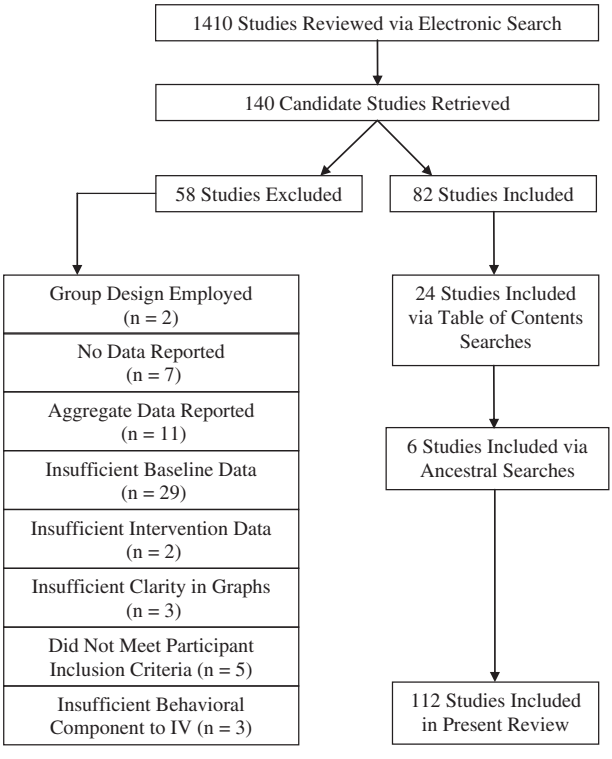

Figure 1. Schematic overview of the identification, inclusion, and exclusion of studies for review. Note that some studies met more than one exclusion criterion.

as open or closed, and any additional diagnoses (e.g., seizure disorder, attention deficit hyperactivity disorder).

Target Responses

Behaviors targeted in the articles were coded as either *acquisition* or *reduction* targets, and a description of the target behavior was recorded. In addition, acquisition target responses were classified using the following categories: academic skills, compliance with academic skills, social skills, activities of daily living, motor skills, compliance with physical exercise, language skills, leisure activities, therapy attendance, vocational tasks, problem solving, home accident prevention skills, health-related activities of daily living, orientation questions, help-recruiting behaviors, and self-awareness skills. Reduction target responses were classified using the following categories: inappropriate vocalizations, aggression, disruptive behavior,

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insomnia, excessive vocalizations, impulsive behavior, noncompliance, elopement, inappropriate sexual behavior, destructive behavior, stereotypy, restraint, delusional statements, self-injurious behavior, food refusal, and others.

Intervention Characteristics

Descriptions of the interventions used, whether they were included in an eclectic intervention package, the setting of the intervention (i.e., analog or naturalistic), change agent, and duration of the intervention were recorded. In addition, interventions were classified on the basis of the chapter structure of ABA (Cooper, Heron, & Heward, 2007).[2] Interventions used in acquisition evaluations were classified using the following categories: reinforcement, antecedent variables, imitation, shaping, chaining, contingency contract, token economy, group contingencies, and self-management procedures. In addition, fluency training and direct instruction were added to this intervention category. These interventions are not covered in ABA (Cooper et al., 2007); however, they are both behavioral approaches for teaching skills to individuals with disabilities and appear in the ABI rehabilitation literature (Chapman, Ewing, & Mozzoni, 2005; Glang, Singer, Cooley, & Tish, 1992). Interventions used in behavior-reduction evaluations were classified using the following categories: punishment, extinction, differential reinforcement, contingency contract, group contingencies, self-management, and antecedent intervention. In addition, the type of functional assessment (e.g., antecedent-behavior-consequence [ABC] observation, functional analysis) and the reinforcement function determined by the authors were recorded for behaviors targeted for reduction.

Experimental Procedures

The type of SCD was recorded for each evaluation. In addition, articles were coded for the presence of interobserver agreement (IOA) assessment, procedural integrity assessment, maintenance or follow-up data, transfer of an intervention to another environment, and the assessment of social validity.

Effect Size Calculations

In order to calculate effect size indices for each evaluation, data were extracted from graphs published in each article using the Grab It! Graph Digitizer software application. Standard mean difference (SMD) and percentage of nonoverlapping data

[2] Cooper et al. (2007) is widely considered the leading textbook in applied behavior analysis.

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(PND) were calculated as measures of intervention effectiveness for each evaluation.[3] To calculate SMD scores, the average of the intervention data points was subtracted from the average of the baseline data points and divided by the standard deviation (*SD*) of the baseline data points. To calculate PND scores, the percentage of data points during intervention that surpassed the extreme values in baseline was calculated. The PND score was not calculated for evaluations in which a data point in baseline was reported at the ceiling or floor as suggested by Scruggs and Mastropieri (1998).

The following rules for comparing data from experimental phases within an evaluation were used in all of the aforementioned effect size calculations: (i) if a reversal (e.g., ABAB) design was employed, an effect was calculated from the first baseline phase and the last intervention phase; (ii) if a multi-element design was employed, an effect was calculated from the superior intervention data and baseline data; (iii) if a multiple baseline design was employed, an effect was calculated from the first baseline and the last intervention phase for each person, setting, or behavior; and (iv) if a changing criterion design was employed, an effect was calculated using the first baseline phase and the last intervention criterion phase. The following rules were also used to address the additional research designs that were employed: (i) if a nonexperimental design was used (e.g., AB design), an effect was calculated using the first baseline and the last intervention phase for each intervention that was evaluated; (ii) if a multiple baseline design with an embedded reversal was used, an effect was calculated using the first baseline and last intervention phase for each person, setting, or behavior; (iii) if a changing criterion design with an embedded reversal was used, an effect was calculated using the first baseline and last intervention criterion phase; and (iv) if a multiple baseline design with an embedded multi-element design was used, an effect was calculated from the superior intervention and baseline data for each person, setting, or behavior.

Evidence-based Practice Classifications

A final purpose of the current review was to determine if behavioral rehabilitative interventions for ABI meet the evidence-based practice criteria described by the APA Division 12 Task Force (Chambless & Ollendick, 2001) and Horner et al. (2005).[4]

[3] Tau_{novlap}, a recently proposed effect size metric for single-case design research, was also calculated for each individual intervention evaluation. To the authors' knowledge, no benchmarks have been published on how Tau_{novlap} scores should be interpreted. Thus, these data are not presented in this article but are available from the first author upon request.

[4] It should be noted that the authors used evidence-based practice criteria to evaluate this literature that were not in place when much of the research was published. It may be the case that these criteria are arbitrary and better used to evaluate research published after 2001 (for the American Psychological Association Division 12 criteria) or 2005 (for the Horner et al. criteria). However, the use of such criteria seems necessary to systematically review the 30-year span of the behavioral rehabilitative literature and provide recommendations for clinicians and researchers working in this subfield of applied behavior analysis.

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Each intervention category that was identified was evaluated using criteria from both levels of evidence systems. For the APA Division 12 criteria, an evaluation was assessed to determine the following: (i) if efficacy was demonstrated by finding that the intervention was superior to another intervention or to no intervention using a sound experimental design (i.e., ABAB, multiple baseline, alternating treatments, or changing criterion designs) using visual inspection of graphed data; (ii) if researchers used a treatment manual or provided a clear operational definition of the intervention; and (iii) if participant characteristics were clearly specified (i.e., age, gender, time since injury, and type of injury). To determine intervention efficacy, effect sizes were calculated for each evaluation. Interventions were determined to be effective if the SMD score was calculated to be 0.5 or greater, indicating at least a medium effect. An intervention category was classified as *well established* if a minimum of nine studies from the category met the aforementioned criteria with at least two studies having been conducted by independent investigators. An intervention category was classified as *probably efficacious* if three to eight studies met the aforementioned criteria, and if fewer than three studies met the aforementioned criteria, the intervention category was classified as *experimental*.

For the guidelines outlined by Horner et al. (2005), an evaluation was assessed to determine the following: (i) if the intervention was operationally defined; (ii) if the context in which the practice was used was defined; (iii) the practice was implemented with fidelity (i.e., if IOA and procedural integrity data were collected); and (iv) if results documented that the practice was functionally related to change in dependent measures (i.e., the intervention was introduced and removed at three points in time or across three or more data series [e.g., participants, settings] using multiple baseline, reversal, alternating treatment, or changing criterion designs) using visual inspection of graphed data. An intervention category was considered 'evidence based' if the effects of the intervention were replicated across at least five studies by at least three different researchers and the studies included at least a total of 20 participants.

Intercoder Agreement

To assess agreement between coders, point-by-point agreement was calculated by dividing the number of agreements by the number of agreements plus disagreements converted to a percentage. An agreement was defined as both coders recording the same feature (e.g., diagnosis, target behavior, research design) per evaluation. Agreement was assessed for 57 (50.9%) of the 112 articles (i.e., 103 [47.0%] of the 223 evaluations), and mean agreement was 93.1%. An additional variable required intercoder agreement assessment (i.e., whether a functional relationship was demonstrated via visual inspection) when determining if interventions should

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be classified as evidence-based practice. An agreement was defined as both coders recording whether a functional relationship was demonstrated using both the APA Division 12 criteria and the Horner et al. (2005) criteria. Agreement was assessed for 28 (25%) of the 112 articles (i.e., 79 [35.5%] of the 223 evaluations) and was 87.3% and 86.1% for the APA Division 12 and Horner et al. (2005) criteria, respectively. The coders examined and resolved all discrepancies before final codes were applied.

RESULTS

Characteristics of the Literature

Intervention evaluations from the 112 studies identified from the literature search were excluded from coding for the following reasons: (i) if they did not include sufficient quantitative data (i.e., at least two data points in each of the baseline and intervention conditions); (ii) if they did not meet participant inclusion criteria (i.e., have a diagnosed ABI); (iii) if only aggregate data were reported; (iv) if they included a duplicate data set from another identified article; or (v) if they did not include sufficient clarity in graphs to permit the calculation of effect sizes (a complete reference list of the articles included in the present review is available from the first author upon request). Two hundred and twenty three evaluations conducted with a total of 219 participants remained for coding. A total of 26 evaluations were excluded because of insufficient baseline data ($n = 15$), participants not meeting inclusion criteria ($n = 8$), the authors only reporting aggregate data ($n = 1$), insufficient intervention data ($n = 1$), and a duplicate data set being published ($n = 1$). The identified studies were published from 1984 to 2010 with an average of 4.15 ($SD = 2.3$) studies published per year. Articles were identified from a total of 22 journals, and most articles were published in *Brain Injury* ($n = 31$), *Behavioral Interventions* ($n = 20$), and *Journal of Applied Behavior Analysis* ($n = 18$)(refer to Table 1 for an abbreviated list of the journals from which articles were identified for this analysis). The following analyses are separated by focus of the evaluation (i.e., skill acquisition or behavior reduction) when there were meaningful differences. When differences were negligible for certain characteristics (e.g., setting type, IOA), the analyses were conducted for skill-acquisition and behavior-reduction evaluations combined.

Participant Characteristics

Most participants were reported as being 18 years old or older (63.5%), and two participants had no reported age. In addition, 69.9% of participants were male, and

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Table 1. Journals that published articles included in the review.

Journal	*n* (%)
Archives of Physical Medicine and Rehabilitation	6 (5.4)
Behavior Modification	4 (3.6)
Behavioral Interventions	20 (17.9)
Brain Injury	30 (26.8)
Child and Family Behavior Therapy	2 (1.8)
Journal of Applied Behavior Analysis	17 (15.2)
Journal of Behavior Therapy and Experimental Psychiatry	4 (3.6)
Journal of Head Trauma Rehabilitation	12 (10.7)
Neuropsychological Rehabilitation	4 (3.6)
Other	13 (11.6)
Total	112 (100)

30.1% of participants were female. The time since injury was reported for 78.1% of participants and ranged from 12 days to 22 years with a mean of 4.6 years post-injury. Coma length was reported for 30.6% of participants, and the average length of coma reported was 38.3 days (range, <1 day to 7 months). Injury severity (e.g., mild, moderate, severe) was reported for 25.6% of participants with most injuries reported as severe (Figure 2). A coma score was reported for 18.3% of participants, and the modal assessment was the Glasgow scale (Figure 2). Most participants were reported as having sustained a TBI (78.5%) rather than an ABI (19.2%), and most studies (80.5%) did not report whether participants with TBIs had sustained an open or closed injury (Figure 2). Cause of injury was reported for 88.6% of the participants with ABI diagnoses and for 74.7% of participants with a TBI diagnosis (refer to Table 2 for a list of reported causes of injury for participants with ABI and TBI diagnoses). The majority of participants (68.2%) with ABI diagnoses were reported as having additional diagnoses; seizure disorders, amnesia (e.g., severe amnesic syndrome), and diabetes were the most commonly reported diagnoses. The majority of participants (52.3%) with TBI diagnoses were also reported as having additional diagnoses, and paresis, amnesia, and insomnia were most commonly reported.

Target Responses

More behavior-reduction evaluations (60.1%) were identified than skill-acquisition evaluations (37.7%), and four evaluations (1.8%) were coded as both reduction and acquisition (Figure 3). The most common targets in skill-acquisition evaluations were academic skills (16.7%), compliance with academic tasks (8.9%), and social skills (8.9%). The most common targets in behavior-reduction evaluations were inappropriate vocalizations (18.8%), aggression (17.6%), and disruptive behavior (12.1%)

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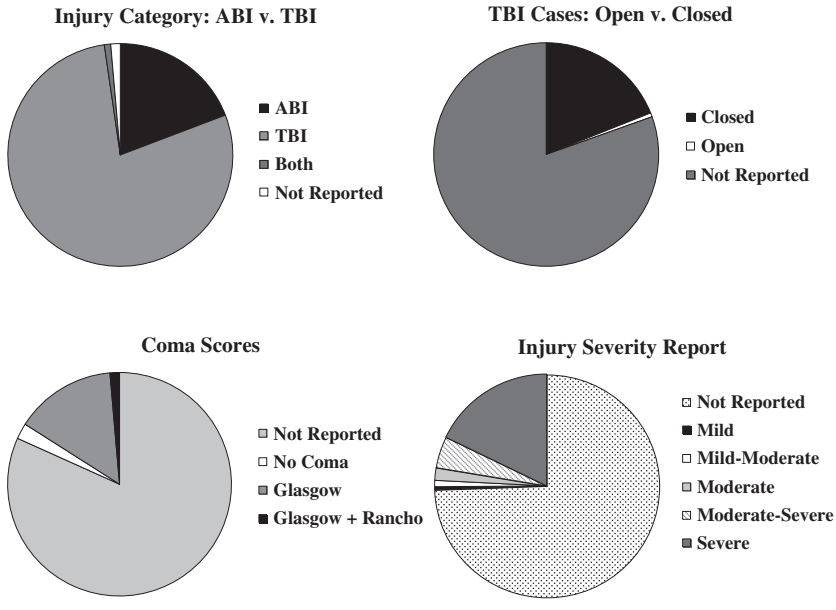

Figure 2. Reported participant characteristics including injury categorization, cases of open and closed traumatic brain injury, reported coma scores, and report of injury severity for all participants.

(refer to Table 3 for an abbreviated list of topographical categories of target responses for both skill-acquisition and behavior-reduction evaluations). In addition, 63.5% of evaluations reported other untargeted problem behaviors exhibited by the participants.

Intervention Characteristics

Overall, most evaluations were coded as implementing only behavioral interventions (81.4%), and 18.6% of the evaluations employed at least one behavioral intervention component embedded in an eclectic package. However, there were fewer eclectic intervention packages implemented in skill-acquisition evaluations (9.1%) compared with behavior-reduction evaluations (18.6%; Figure 3). Setting type was reported for 97.3% of the evaluations, with interventions most commonly implemented in naturalistic settings (81.5%) (Figure 4). At least one change agent was reported in 84.1% and 93.5% of skill-acquisition and behavior-reduction evaluations, respectively. Experimenters (28.1%), teachers (24.0%), and therapists (13.5%) were reported most often for implementing interventions in skill-acquisition studies, whereas staff (26.2%), therapists (24.4%), and experimenters (14.0%) were reported most often for implementing reduction procedures. The real-time span of

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Table 2. Reported causes of participants' brain injuries.

Reported cause of injury	*n* (%)
Acquired brain injury	
Hydrocephalus	5 (11.4)
Seizure disorder or activity	5 (11.4)
Aneurysm or rupture of the communicating artery	4 (9.1)
Cardiac arrest	3 (6.8)
Suicide attempt (drug overdose or hanging)	3 (6.8)
Diabetic coma	2 (4.5)
Hepatitis	2 (4.5)
Herpes simplex virus	2 (4.5)
Stroke	2 (4.5)
Subarachnoid hemorrhage	2 (4.5)
Viral encephalitis	2 (4.5)
Other	7 (15.9)
Cause of injury not reported	5 (11.4)
Total	44 (100)
Traumatic brain injury	
Motor vehicle or road traffic accident	83 (47.7)
Pedestrian v. car	12 (6.9)
Fall	9 (5.2)
Struck by car while riding bike or moped	8 (4.6)
Assault	4 (2.3)
Gunshot wound	2 (1.1)
Shaken baby syndrome	2 (1.1)
Struck by object (golf club or bat)	2 (1.1)
Other	8 (4.6)
Cause of injury not reported	44 (25.3)
Total	174 (100)

intervention implementation was reported in 60.2% and 69.6% of skill-acquisition and behavior-reduction evaluations, respectively. The mean duration of intervention for skill-acquisition evaluations was 47.4 days (range, 11–196 days), whereas the mean duration of intervention for behavior-reduction evaluations was 148.9 days (range, 14 days–4 years).

Most skill-acquisition evaluations (85.2%) assessed the effects of a single intervention; however, multiple interventions were assessed in some evaluations (e.g., using a multi-element design), with a maximum of four interventions assessed in one evaluation. A total of 108 interventions were assessed in skill-acquisition evaluations. Most behavior-reduction evaluations (83.3%) also assessed the effects of a single intervention to reduce a target behavior; however, a maximum of five interventions were assessed in one behavior-reduction evaluation. A total of 171 interventions were assessed in behavior-reduction evaluations. Interventions used in skill-acquisition evaluations were most commonly coded into two intervention categories (66.7%) (e.g., self-management and reinforcement), whereas interventions used in behavior-reduction evaluations were most

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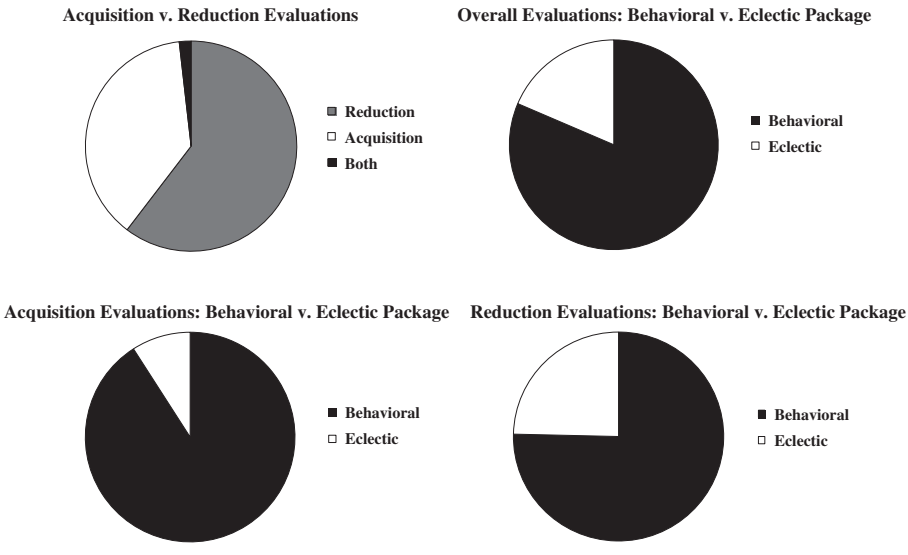

Figure 3. Intervention characteristics.

commonly coded into one intervention category (55.0%; e.g., differential reinforcement). A total of 218 and 282 intervention categories were coded for skill-acquisition and behavior-reduction evaluations, respectively. The most commonly coded intervention categories for skill-acquisition evaluations were reinforcement (34.9%), antecedent variables (29.8%), and self-management (22.5%). The most commonly coded intervention categories for behavior-reduction evaluations were differential reinforcement (30.9%), antecedent interventions (27.7%), and punishment (19.2%; refer to Table 4 for more detailed information).

Most of the behavior-reduction evaluations (69.6%) reported no functional assessment before designing an intervention. When functional assessment procedures were employed, the use of a single assessment was most common (18.1%), with the most commonly reported procedures being descriptive assessment (e.g., ABC observations, conditional probability analysis) (40.0%) and the functional analysis (29.2%). The majority of evaluations employing functional assessment reported identifying a single behavioral function (85.7%), with escape being the modal function of problem behavior (refer to Figure 5 for more detailed information).

Experimental Procedures

The multiple baseline design was the most frequently used experimental design for both skill-acquisition and behavior-reduction evaluations (47.7% and 37.7%,

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Table 3. Topographical categories of target responses in skill-acquisition and behavior-reduction evaluations.

Topographical category	*n* (%)
Skill acquisition	
Academic skills	15 (16.7)
Compliance with academic tasks	8 (8.9)
Social skills	8 (8.9)
Activities of daily living	7 (7.8)
Motor skills	7 (7.8)
Compliance with physical exercise	6 (6.7)
Language skills	6 (6.7)
Leisure activities	6 (6.7)
Therapy attendance	6 (6.7)
Vocational tasks	6 (6.7)
Problem solving	5 (5.6)
Home accident prevention skills	4 (4.4)
Total	90 (100)
Behavior reduction	
Inappropriate vocalizations	31 (18.8)
Aggression	29 (17.6)
Disruptive behavior	20 (12.1)
Insomnia	12 (7.3)
Excessive vocalizations	9 (5.5)
Impulsive behavior	8 (4.8)
Noncompliance	8 (4.8)
Elopement	6 (3.6)
Inappropriate sexual behavior	6 (3.6)
Destructive behavior	5 (3.0)
Stereotypy	5 (3.0)
Restraint	4 (2.4)
Total	165 (100)

respectively), followed by the reversal design (18.2% and 27.5%, respectively) and nonexperimental designs (17.0% and 23.9%, respectively). IOA was reported in 64.4% of evaluations, whereas procedural integrity was only reported in 7.2% of the evaluations (Figure 4). In addition, maintenance of the intervention effect was reported in 36.5% of evaluations, and 13.1% of evaluations reported transferring the intervention to another environment with home, community, and a naturalized intervention setting most commonly reported as transfer environments (Figure 4). Social validity was assessed in 16.7% of evaluations (Figure 4), and most social validity measures assessed either the social acceptability of interventions (58.5%) or the social importance of intervention outcomes (39.6%); only one evaluation assessed the social importance of behavior change goals (i.e., if the goal that had been targeted for intervention was a meaningful goal for the participant).

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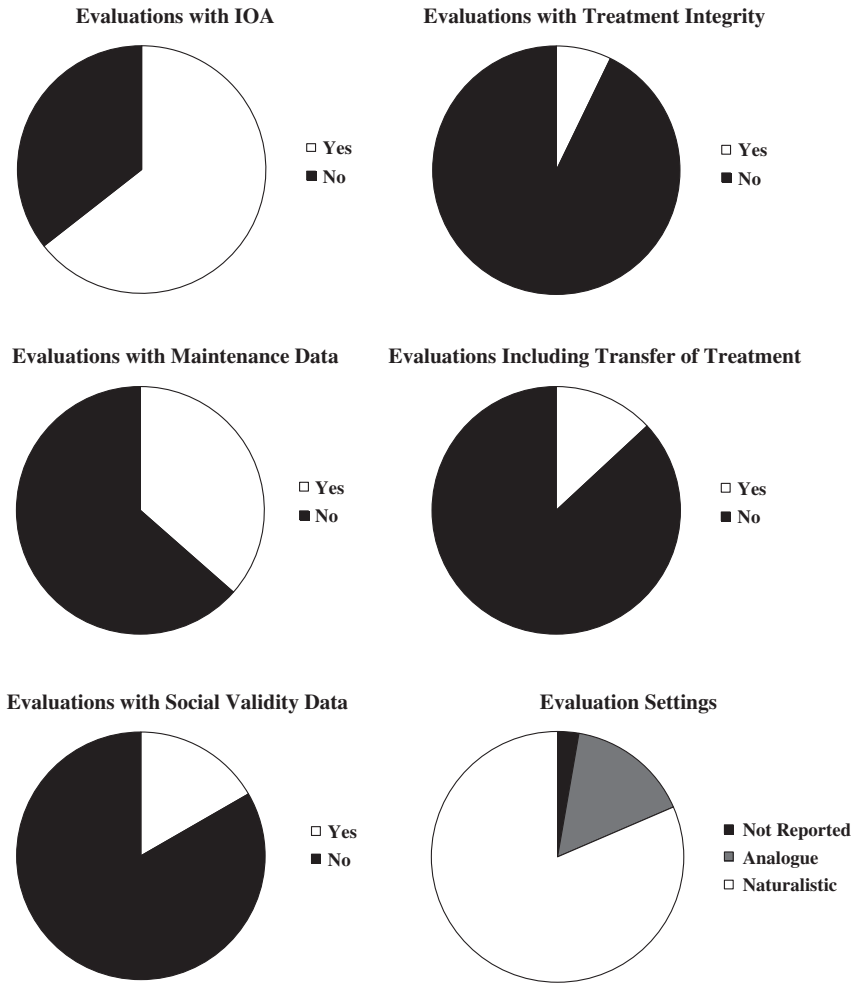

Figure 4. Methodology characteristics.

Evidence-based Standards Classification

Of the 11 skill-acquisition intervention categories, both reinforcement (with 14 studies meeting efficacy criteria with 34 participants) and antecedent variables (with 12 studies meeting efficacy criteria with 25 participants) were classified as well established using the APA Division 12 criteria (Table 5). The mean SMD and PND values for reinforcement were 14.1 ($SD = 37.0$) and 89.6 ($SD = 28.8$), respectively. The mean SMD and PND values for antecedent variables were 20.0 ($SD = 44.8$) and 96.0 ($SD = 27.1$), respectively. In addition, self-management was

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Table 4. Intervention categories employed in skill-acquisition and behavior-reduction evaluations.

Intervention category	*n* (%)
Skill acquisition	
Reinforcement	76 (34.9)
Antecedent variables	65 (29.8)
Self-management	49 (22.5)
Group contingencies	9 (4.1)
Fluency training	5 (2.3)
Chaining	4 (1.8)
Token economy	4 (1.8)
Contingency contract	2 (.9)
Direct instruction	2 (.9)
Imitation	2 (.9)
Shaping	0 (0)
Total	218 (100)
Behavior reduction	
Differential reinforcement	87 (30.9)
Antecedent interventions	78 (27.7)
Punishment	54 (19.2)
Self-management	33 (11.7)
Extinction	26 (9.2)
Contingency contracting	4 (1.4)
Group contingencies	0 (0)
Total	282 (100)

classified as probably efficacious with eight studies meeting criteria with 20 participants. The mean SMD and PND values for this intervention category were 18.0 ($SD = 42.1$) and 92.1 ($SD = 31.9$), respectively. The remaining intervention categories for skill-acquisition evaluations (i.e., group contingencies, fluency training, chaining, token economy, contingency contract, direct instruction, imitation, and shaping) were classified as experimental. There were no studies that met the APA Division 12 criteria for the majority of these intervention categories. However, one study was considered efficacious for the group contingencies, fluency training, and imitation categories (with three, five, and two participants, respectively; refer to Table 5 for the mean SMD and PND values for the intervention categories classified as experimental).

Of the seven behavior-reduction intervention categories, three interventions were classified as well established using the APA Division 12 criteria (Table 5). Differential reinforcement was employed in 20 studies that met efficacy criteria with 35 participants, and the mean SMD and PND values for this intervention category were 4.9 ($SD = 4.5$) and 90.0 ($SD = 19.4$), respectively. Antecedent interventions were employed in 14 studies that met efficacy criteria with 29 participants, and the mean SMD and PND values for this intervention category were 4.0 ($SD = 3.6$) and 70.7

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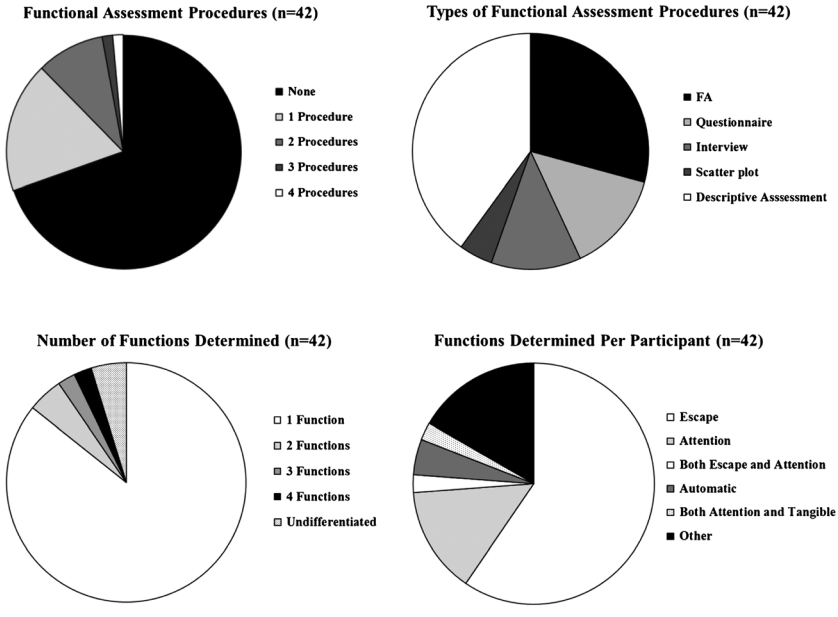

Figure 5. Reported functional assessment procedures, types of procedures, number of functions determined, and reported functions per participant.

(*SD* = 37.9), respectively. Punishment was employed in nine studies that met efficacy criteria with 19 participants, and the mean SMD and PND values for this intervention category were 5.6 (*SD* = 5.3) and 86.5 (*SD* = 23.2), respectively. In addition, both self-management (with four studies meeting efficacy criteria with 12 participants) and extinction (with three studies meeting efficacy criteria with 13 participants) were classified as probably efficacious. The mean SMD and PND values for self-management were 4.1 (*SD* = 3.3) and 90.8 (*SD* = 14.1), respectively. The mean SMD and PND values for extinction were 5.0 (*SD* = 6.0) and 87.3 (*SD* = 19.3), respectively. Both contingency contracting and group contingencies were classified as experimental. Contingency contracting was employed in one study with one participant that met efficacy criteria, and no studies employing group contingencies met efficacy criteria (refer to Table 5 for the mean SMD and PND values for the intervention category classified as experimental).

According to the guidelines outlined by Horner et al. (2005), no skill-acquisition or behavioral-reduction intervention categories met the criteria to be considered evidence based. Only two skill-acquisition studies met the Horner et al. (2005) criteria (i.e., Davies, Jones, & Rafoth, 2010; Gajar, Schloss, Schloss, & Thompson, 1984). Gajar et al. (1984) employed interventions in the reinforcement, self-management, and imitation categories, and Davies et al. (2010) employed a self-management

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Table 5. American Psychological Association Division 12 classification of skill-acquisition and behavior-reduction intervention categories.

Intervention category	Number of studies (and participants) employing intervention	Number of studies (and participants) that met criteria	Classification	Mean SMD	Mean PND
Skill acquisition					
Reinforcement	29 (63)	14 (34)	Well established	14.1	89.6
Antecedent variables	29 (61)	12 (25)	Well established	20.0	96.0
Self-management	15 (41)	8 (20)	Probably efficacious	18.0	92.1
Group contingencies	2 (9)	1 (3)	Experimental	4.0	87.5
Fluency training	1 (5)	1 (5)	Experimental	2.7	76.5
Chaining	2 (4)	0 (0)	Experimental		
Token economy	1 (2)	0 (0)	Experimental		
Contingency contract	1 (2)	0 (0)	Experimental		
Direct Instruction	1 (2)	0 (0)	Experimental		
Imitation	1 (2)	1 (2)	Experimental	6.7	100
Shaping	0 (0)	0 (0)	Experimental		
Behavior reduction					
Differential reinforcement	46 (75)	20 (35)	Well established	4.9	90.0
Antecedent interventions	39 (63)	14 (29)	Well established	4.0	70.7
Punishment	30 (46)	9 (19)	Well established	5.6	86.5
Self-management	13 (28)	4 (12)	Probably efficacious	4.1	90.8
Extinction	14 (26)	3 (13)	Probably efficacious	5.0	87.4
Contingency contracting	3 (4)	1 (1)	Experimental	1.8	94.1
Group contingencies	0 (0)	0 (0)	Experimental		

SMD, standard mean difference; PND, percentage of nonoverlapping data.

intervention. Similarly, only two behavioral-reduction studies met the Horner et al. (2005) criteria (i.e., Kennedy, 1994; Mottram & Berger-Gross, 2004). Mottram and Berger-Gross (2004) employed interventions in the differential reinforcement and punishment categories, and Kennedy (1994) employed antecedent interventions.

DISCUSSION

Results Summary

Studies employing behavioral interventions in ABI rehabilitation have been published in over 20 peer-reviewed journals from multiple fields such as ABA, rehabilitation, school psychology, and occupational therapy. In addition, the annual frequency of these publications has remained low and variable over the past few decades. Because of both the nature of the present review (i.e., a focus on SCD research) and the quality of the research identified, many of the studies (e.g., 58 of the 140 studies identified via the initial literature search) and some individual

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evaluations had to be excluded from the analyses. The most common reason for the exclusion of studies and evaluations was an insufficient amount of reported baseline data.

One purpose of this meta-analysis was to expand on previous literature reviews by reporting detailed characteristics of participants, interventions, outcomes, and the methodology used in SCD research with individuals an ABI diagnosis. The majority of participants in the identified studies were men over the age of 18 years, and while authors commonly reported some characteristics such as time post-injury, many other key participant characteristics such as injury severity and coma scores were not commonly reported. More behavior-reduction evaluations were identified than skill-acquisition evaluations, and a wide range of responses were targeted for both intervention types. Most evaluations implemented only behavioral interventions (compared with eclectic treatment packages), and one change agent most commonly implemented interventions in a natural setting. In addition, the mean duration of intervention was found to be longer for behavior-reduction studies compared with skill-acquisition studies. The multiple baseline design and reversal designs were the most frequently used experimental design for both skill-acquisition and behavior-reduction evaluations; however, many authors reported the use of nonexperimental designs for both evaluation types.

The current review also aimed to analyze the use of functional assessment in behavior-reduction evaluations. The results suggest that functional assessment is commonly not used before reductive behavioral interventions are designed for individuals in ABI rehabilitation. When functional assessment procedures were employed, the use of a single assessment was most common, and the most commonly reported procedure was descriptive assessment (e.g., ABC observations, scatterplot, conditional probability analysis). It may be the case that descriptive assessment procedures are commonly used in this literature because these procedures are more objective than indirect assessment procedures (e.g., interviews, rating scales), yet they do not require as much time, resources, or expertise as the functional analysis. However, the use of only descriptive assessment procedures may be problematic because the data they generate are only correlational. In the present analysis, escape was reported to be the modal function of problem behavior. This is consistent with a review of the functional analysis literature by Hanley, Iwata, and McCord (2003), which found that escape was the most common problem behavior function for the participants in the articles they reviewed (the majority having a developmental disability diagnosis). Finally, the effect size calculations in the current review may reflect the limited use of functional assessment procedures. Although effect sizes for both skill-acquisition and behavior-reduction intervention categories were generally large, the scores were found to be smaller for behavior-reduction evaluations.

Another purpose of the present review was to classify behavioral interventions in a more detailed manner than in previous reviews by using the chapter structure of

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Applied Behavior Analysis (Cooper et al., 2007). The results suggest that both skill-acquisition and behavior-reduction evaluations commonly assessed the effects of a single intervention. Also, interventions used in skill-acquisition evaluations were most commonly classified into two categories: self-management and reinforcement. Interventions used in behavior-reduction evaluations were most commonly classified into one category: differential reinforcement. Reinforcement and antecedent variables were most commonly coded in skill-acquisition evaluations, and differential reinforcement and antecedent interventions were most commonly coded in behavior-reduction evaluations. The finding that these interventions are commonly used in the ABI population was not particularly surprising, as this finding seems to be consistent with the literature on developmental disabilities (Brosnan & Healy, 2011; Reid, Phillips, & Green, 1991).

Finally, this review aimed to classify behavioral interventions using two existing evidence-based practice frameworks along with quantitative measurements of intervention effectiveness (i.e., effect size calculations). Using the APA Division 12 criteria, reinforcement and antecedent variables were deemed well established as skill-acquisition interventions, and self-management was deemed probably efficacious. In addition, differential reinforcement, antecedent interventions, and punishment were deemed well established as behavior-reduction interventions, and both self-management and extinction were deemed probably efficacious for reducing problem behavior. None of the intervention categories for both intervention types were considered evidence based according to the guidelines outlined by Horner et al. (2005). In addition, the effect sizes that were calculated were found to be very large, indicating that behavioral interventions were generally quite effective in both teaching skills and reducing problem behavior in this population.

Methodological Concerns with the Behavior-Analytic Acquired Brain Injury Literature

After evaluating the results of this meta-analysis, the methodological rigor of the investigations in this literature is worth analysis. Horner et al. (2005) offer a list of quality methodological indicators to help determine whether a SCD research study should be considered acceptable. One key quality indicator is a detailed description of a study's participants and setting. From the current review, authors in this literature commonly reported some participant characteristics and the type of research setting. However, other important participant characteristics were often not reported (e.g., coma score, injury severity, description of the injury, additional diagnoses), which does not fulfill the recommendation that participants should be 'described with sufficient detail to allow others to select individuals with similar characteristics' (Horner et al., 2005, p. 174). The use of technological descriptions of participants is important for direct replications of previous investigations. In addition, adequate descriptions of

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participants may aid researchers in interpreting results of investigations in which some participants responded to treatment while others did not.

Horner et al. (2005) also recommend that researchers describe dependent variables with operational and replicable precision, measure the dependent variable repeatedly over time, and report IOA for dependent variables that meet the field's standards. In the current review, subjective or global descriptions of dependent variables were found in many studies. For example, the most commonly reported target responses in behavior-reduction studies were aggression and disruptive behavior. Also, several studies and a few individual evaluations had to be excluded from the analyses because of an insufficient amount of either baseline or intervention data being collected or because the authors reported aggregate data rather than repeated measures data. Finally, IOA was absent for 35.6% of the evaluations in the current meta-analysis.

At least two factors should be considered when explaining the lack of technological descriptions, repeated measurement, and collection of IOA for dependent variables found in the current review. First, journals that are not familiar with SCD research employing behavioral interventions may not have as stringent of editorial requirements as behavior analytic journals. For example, the *JABA* website includes descriptions of certain manuscript requirements to potential authors such as the importance of providing an operational definition of the dependent variable, including data on individual variation, and assessing IOA (Lerman, 2012). While these descriptions positively guide authors (both to evaluate whether their manuscript fits with the scope of the journal and to include certain technological descriptions of the investigation), other journals outside of behavior analysis might not provide such descriptions (or impose related editorial contingencies) for authors of SCD research. Second, collecting repeated measures data and IOA that meet discipline standards requires certain levels of expertise and resources. For example, when answering clinic-driven or field-driven research questions, a clinician or researcher has to plan how he or she will collect data, train other therapists on the data collection system, and schedule time for another therapist to assess IOA for the correct proportion of sessions throughout the course of the study. If this planning does not occur prior to implementing the intervention for a client, this may lead to methodological limitations such as an insufficient number of baseline data points are lack of IOA.

Horner et al. (2005) also recommend that researchers measure procedural fidelity and report social validity data. The results of the present meta-analysis suggest that authors publishing in this literature have rarely followed these recommendations. McIntyre, Gresham, DiGennaro, and Reed (2007) reviewed school-based studies published in JABA between 1991 and 2005 with individuals ages 0–18 years, and the authors found that only 30% of the studies reported treatment integrity data. Articles published in JABA from 1968 to 1998 were also assessed for reports of social validity measures, and the authors found that less than 13% of articles reported

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treatment outcome and acceptability measures (Carr, Austin, Britton, Kellum, & Bailey, 1999). Assuming that other journals outside of behavior analysis are less familiar with procedural fidelity and social validity measurement in SCD research, the lack of these data in the current review was not particularly surprising. In addition (similar to IOA assessment), several factors such as required expertise, resources, and planning may also account for the lack of procedural fidelity and social validity measurement.

Finally, Horner et al. (2005) recommend the use of experimental designs that provide 'at least three demonstrations of experimental effect at three different points in time' and the demonstration of experimental control (p. 174). Although the multiple baseline and reversal designs were found to be the most frequently used designs in the current meta-analysis, many authors reported the use of nonexperimental designs for both skill-acquisition and behavior-reduction evaluations. If we were to have removed evaluations employing nonexperimental designs (i.e., case studies), we would have eliminated a substantial portion of the evaluations identified in the literature search (i.e., 17.0% and 23.9% of skill-acquisition and behavior-reduction evaluations, respectively). The use of nonexperimental designs in this area of literature may be due to aspects of field settings that commonly evaluate treatments experimentally. If behavioral interventions are being implemented in a neurorehabilitation facility or in a client's home, the contingencies that support the use of experimental designs may be absent. The use of nonexperimental designs may also be occurring because of a repertoire deficit on the part of the change agent. That is, change agents working in field settings may hold the misconception that it is too difficult or too time-consuming to employ experimental designs.

Limitations of the Present Review

A few limitations should be considered when evaluating the results of the current meta-analysis. First, the intervention categories that were assessed using the evidence-based practice frameworks were often components of a behavioral intervention package (e.g., self-management and reinforcement; differential reinforcement and extinction). The number of intervention categories included in skill-acquisition and behavior-reduction evaluations ranged from 1 to 3 and 1 to 4 categories, respectively. Therefore, when an evaluation met (or did not meet) efficacy criteria in the current review, it was not possible to determine which components of the package were responsible for the effect of the intervention. This limitation may also be considered in light of the intervention categories being assessed. That is, when intervention categories met or did not meet evidence-based practice criteria, it remains undetermined if the specific intervention met criteria due to its effectiveness as a solitary intervention or if its effectiveness was due to the combination of the intervention with other intervention components in the behavioral treatment package.

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Another limitation of the current review is the disadvantages associated with the chosen quantitative measurements of intervention effectiveness. The effect sizes in the current meta-analysis were chosen because of their common use in the analysis of SCD studies. While SMD and PND have a greater probability of being interpreted by SCD researchers and have published criteria for interpreting calculations (e.g., Cohen, 1988; Scruggs & Mastropieri, 1998), they also have limitations. Although there is little to no consensus on which metrics are most appropriate for SCD research and each measure does have its own disadvantages, future investigations may consider the use of other nonoverlap metrics and effect size indicators outside of nonoverlap metrics such as multi-level models (e.g., van den Noortgate & Onghena, 2008) and regression models (e.g., Huitema & McKean, 2000) when quantifying the effectiveness of SCD studies (Beretvas & Chung, 2008).

Another limitation of the current review is the stringent nature of some of the guidelines outlined by Horner et al. (2005). In this particular evidence-based framework, interventions are required to be implemented with fidelity. While IOA was assessed for the majority of evaluations assessed in the current review, procedural integrity data were rarely reported. As previously mentioned, it has been found that only 30% of the studies published in a high quality behavior analytic journal that routinely publishes SCD research (i.e., JABA) report procedural integrity data (McIntyre et al., 2007). This guideline may be considered too strict as it resulted in all but 5 of the 112 studies in the current review to not meet efficacy criteria. In addition, the Horner et al. (2005) guidelines require that interventions be introduced and removed at three points in time or across three or more data series (e.g., participants, settings) using multiple baseline, reversal, alternating treatment, or changing criterion designs. This guideline may also be considered too strict because it excludes designs that still adequately demonstrate experimental control and control for threats to internal validity (e.g., multiple baseline design across two participants, settings, or behaviors).

Although some of the Horner et al. (2005) guidelines discussed previously may be considered too stringent, it is worth noting that these guidelines are important, and their use will most likely continue for several reasons. First, the APA Division 12 criteria are not an ideal substitute for the Horner et al. (2005) guidelines because of their vague nature for evaluating SCD research. For example, Division 12 guidelines require manualized treatment in group design research, which is much more precise than requiring a clear operational definition of the intervention in SCD research. Second, the guidelines outlined by Horner et al. (2005) have already been used by the federal What Works Clearinghouse to make informed decisions about intervention practices in schools (Kratochwill et al., 2010). Finally, behavior analysts and experts in SCDs, unlike the criteria developed by APA's Division 12, developed the Horner et al. (2005) guidelines.

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The broad scale of the current meta-analysis may also be considered a limitation. The current review aimed to extend previous reviews by expanding the inclusion criteria to participants of any age with an ABI diagnosis in both skill-acquisition and behavior-reduction evaluations. While the breadth of this review allows for a more extensive analysis of the literature such as comparisons between evaluations targeting skill acquisition and behavior reduction, it does not permit the identification of specific holes in the literature that might guide researchers interested in adding to this area of the literature. Perhaps narrowing the focus of future reviews (e.g., evaluating the effectiveness of antecedent interventions in ABI rehabilitation) would allow for greater precision of analyses, the identification of specific lines of research that are in need of systematic replications, and the identification of certain target responses that have not been evaluated.

Conclusion and Recommendations

The current review aimed to contribute to the ABI rehabilitation literature by addressing many of the limitations of the previous reviews of the behavioral intervention literature for individuals with ABI. First, the current review attempted to include all behavioral intervention studies with all participants with an ABI diagnosis to avoid a restricted population (e.g., adults with a TBI diagnosis). Second, the current review used evidence-based standards frameworks (e.g., APA Division 12 criteria) that are commonly used in psychological research and had not been used in the previous reviews. Third, quantitative measures of effectiveness were calculated for each treatment evaluation, which had not been performed in previous reviews. Finally, the use of functional assessment was coded and interventions were categorized in a more parsimonious manner based on the suggestion by Slifer and Amari (2009) to use descriptive terms that have been developed by the field of ABA. Slifer and Amari (2009) suggest that authors should make meaningful distinctions when reviewing the ABI literature to aid the integration with the existing behavior analytic literature.

Because of the methodological that have been identified in the behavioral intervention ABI literature, it may prove beneficial to provide some recommendations for researchers to aid in improving the rigor in this area. It may prove useful for researchers and clinicians to use the Horner et al. (2005) guidelines as a resource when either planning a research study or before implementing intervention for a client with an ABI under circumstances that might lead to publication. Following the Horner et al. (2005) guidelines may guide researchers and clinicians to avoid the current methodological limitations of the investigations evaluated in the current review such as the lack of technological descriptions of participants, dependent variables, and the intervention being evaluated. It might also guide researchers and clinicians to plan for the necessary resources it takes to collect measures such as

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IOA, procedural fidelity, and social validity in a field setting. Finally, researchers and clinicians might consider the use of experimental designs that are more practical for field settings such as an alternating treatments design or nonconcurrent multiple baseline design (Cooper et al., 2007). These designs still allow for the demonstration of experimental control and can control for threats to internal validity, and they also allow more flexibility for field settings where a return to baseline conditions in a reversal design or the simultaneous collection of baseline across participants in a multiple baseline design may not be feasible.

Overall, the present review identified that behavioral intervention in ABI rehabilitation is a large literature that has shown large effect sizes across a wide variety of behavioral excesses and deficits experienced by 219 individuals with brain injury. Although numerous concerns with the methodological rigor of this literature have been discussed previously, several behavioral interventions were classified as well established and several more were classified as probably efficacious according to the APA Division 12 guidelines. This evidence should communicate to researchers interested in contributing to this area that there are both well-conducted studies and room for improvement in this literature.

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REFERENCES

Beretvas, S. N., & Chung, H. (2008). A review of meta-analyses of single-subject experimental designs: Methodological issues and practice. *International Journal of Language & Communication Disorders*, *2*, 129–141.

Brosnan, J., & Healy, O. (2011). A review of behavioral interventions for the treatment of aggression in individuals with developmental disabilities. *Research in Developmental Disabilities*, *32*, 437–446.

Carr, J. E., Austin, J. L., Britton, L. N., Kellum, K. K., & Bailey, J. S. (1999). An assessment of social validity trends in applied behavior analysis. *Behavioral Interventions*, *14*, 223–231.

Cattelani, R., Zettin, M., & Zoccolotti, P. (2010). Rehabilitation treatments for adults with behavioral and psychosocial disorders following acquired brain injury: A systematic review. *Neuropsychology Review*, *20*, 52–85.

Chambless, D. L., & Ollendick, T. H. (2001). Empirically supported psychological interventions: Controversies and evidence. *Annual Review of Psychology*, *52*, 685–716.

DOI: 10.1002/bin

Chapman, S. S., Ewing, C. B., & Mozzoni, M. P. (2005). Precision teaching and fluency training across cognitive, physical, and academic tasks in children with traumatic brain injury: A multiple baseline study. *Behavioral Interventions*, *20*, 37–49.

Cicerone, K. D., Dahlberg, C., Malec, J. F., Langenbbahn, D. M., Felicetti, T., Kneipp, S., … Catanese, J. (2005). Evidence-based cognitive rehabilitation: Updated review of the literature from 1998 through 2002. *Archives of Physical Medicine and Rehabilitation*, *86*, 1681–1691.

Cohen, J. (1988). Statistical power analysis for the behavioral sciences (2nd edn). Mahwah, NJ: Lawrence Erlbaum Associates.

Cooper, J. O., Heron, T. E., & Heward, W. L. (2007). Applied behavior analysis (2nd edn). Upper Saddle River, NJ: Pearson/Merrill-Prentice Hall.

Davies, S. C., Jones, K. M., & Rafoth, M. A. (2010). Effects of a self-monitoring intervention on children with traumatic brain injury. *Journal of Applied School Psychology*, *26*, 308–326.

Edlund, W., Gronseth, G., So, Y., & Franklin, G. (2004). Clinical practice guideline process manual. St Paul, MN: American Academy of Neurology.

Faul, M., Xu, L., Wald, M. M., & Coronado, V. G. (2010). Traumatic brain injury in the United States: Emergency department visits, hospitalizations, and deaths. Atlanta, GA: Centers for Disease Control and Prevention, National Center for Injury Prevention and Control.

Gajar, A., Schloss, P. J., Schloss, C. N., & Thompson, C. K. (1984). Effects of feedback and self-monitoring on head trauma youths' conversation skills. *Journal of Applied Behavior Analysis*, *17*, 353–358.

Glang, A., Singer, G., Cooley, E., & Tish, N. (1992). Tailoring direct instruction techniques for use with elementary students with brain injury. *Journal of Head Trauma Rehabilitation*, *7*, 93–108.

Gurdin, L. S., Huber, S. A., & Cochran, C. R. (2005). A critical analysis of data-based studies examining behavioral interventions with children and adolescents with brain injuries. *Behavioral Interventions*, *20*, 3–16.

Hanley, G. P., Iwata, B. A., & McCord, B. E. (2003). Functional analysis of problem behavior: A review. *Journal of Applied Behavior Analysis*, *36*, 147–185.

Horner, R. H., Carr, E. G., Halle, J., McGee, G., Odom, A., & Wolery, M. (2005). The use of single-subject research to identify evidence-based practice in special education. *Exceptional Children*, *71*, 165–179.

Hughes, R. S., Barnes, M. P., Baron, J. C., & Brainin, M. L. (2001). European Federation of Neurological Societies guidance for the preparation of neurological management guidelines by EFNS scientific task force. *European Journal of Neurology*, *8*, 549–550.

Huitema, B. E., & McKean, J. W. (2000). Design specification issues in time-series intervention models. *Education and Psychological Measurement*, *60*, 38–58.

Jacobs, H. E. (2000). Behavioral contributions to brain-injury rehabilitation. In J. Austin, & J. E. Carr (Eds.), Handbook of applied behavior analysis (pp. 211–230). Reno, NV: Context Press.

Kennedy, C. H. (1994). Manipulating antecedent conditions to alter the stimulus control of problem behavior. *Journal of Applied Behavior Analysis*, *27*, 161–170.

Kratochwill, T. R., Hitchcock, J., Horner, R. H., Levin, J. R., Odom, S. L., Rindskopf, D. M., & Shadish, W. R. (2010). Single-case designs technical documentation. Retrieved from What Works Clearinghouse website: http://ies.ed.gov/ncee/wwc/pdf/wcc_scd.pdf.

Laatsch, L., Harrington, D., Hotz, G., Marcantuono, J., Mozzoni, M. P., Walsh, V, & Hersey, K. P. (2007). An evidence-based review of cognitive and behavioral rehabilitation treatment studies in children with acquired brain injury. *Journal of Head Trauma Rehabilitation*, *22*, 248–256.

Lash, M. (Ed.). (2007). The essential brain injury guide (4th edn). Vienna, VA: Brain Injury Association of America.

LeBlanc, L. A., Heinicke, M. R., & Baker, J. C. (2013). Expanding the consumer base for behavior-analytic services: Meeting the needs of consumers of the 21st century. *Behavior Analysis in Practice*, *5*, 4–14.

DOI: 10.1002/bin

Lenmkuhl, L. D., Hall, K. M., Mann, N., & Gordon, W. A. (1993). Factors that influence costs and length of stay of persons with traumatic brain injury in acute care and inpatient rehabilitation. *Journal of Head Trauma Rehabilitation*, *8*, 88–100.

Lerman, D. C. (2012, January 9). Preparation of manuscripts for JABA. Retrieved from http://seab.envmed.rochester.edu/jaba/manuscripts.html

Lewin, I. C. F. (1992). Head injuries: Cost and consequences. *Journal of Head Trauma Rehabilitation*, *6*, 76–91.

Limond, J., & Leek, R. (2005). Practitioner review: Cognitive rehabilitation for children with acquired brain injury. *Journal of Child Psychology and Psychiatry*, *46*, 339–352.

McIntyre, L. L., Gresham, F. M., DiGennaro, F. D., & Reed, D. D. (2007). Treatment integrity of school-based interventions with children in the *Journal of Applied Behavior Analysis* 1991–2005. *Journal of Applied Behavior Analysis*, *40*, 659–672.

Mottram, L., & Berger-Gross, P. (2004). An intervention to reduce disruptive behaviours in children with brain injury. *Pediatric Rehabilitation*, *7*, 133–143.

Mozzoni, M. P. (Ed.). (2000). Brain injury [special issue]. *Behavioral Interventions*, *15*(3), 153–277.

Mozzoni, M. P. (Ed.). (2005). Traumatic brain injury [special issue]. *Behavioral Interventions*, *20*(1), 1–120.

Mozzoni, M. P. (2008). Applied behavior analysis evaluation strategies and neurorehabilitation. *Brain Injury Professional*, *5*, 29–31.

Newsome, C., & Hovanitz, C. A. (2005). The nature and value of empirically validated interventions. In J. W. Jacobson, R. M. Foxx, & J. A. Mulick (Eds.), Controversial therapies for developmental disabilities: Fad, fashion, and science in professional practice (pp. 31–44). Mahwah, NJ: Lawrence Erlbaum Associates.

Pace, G. M., & Nau, P. A. (1993). Behavior analysis in brain injury rehabilitation: Training staff to develop, implement, and evaluate behavior change programs. In J. Charles, N. D. Schmidt, & L. Fryer (Eds.), Staff development and clinical intervention in brain injury rehabilitation (pp. 211–230). Gaithersburg, MD: Aspen Publishers.

Reid, D. H., Phillips, J. F., & Green, C. W. (1991). Teaching persons with profound multiple handicaps: A review of the effects of behavioral research. *Journal of Applied Behavior Analysis*, *24*, 319–336.

Scruggs, T. E., & Mastropieri, M. A. (1998). Synthesizing single subject studies: Issues and applications. *Behavior Modification*, *22*, 221–242.

Slifer, K. J., & Amari, K. J. (2009). Behavior management for children and adolescents with acquired brain injury. *Developmental Disabilities Research Reviews*, *15*, 144–151.

van den Noortgate, W., & Onghena, P. (2008). A multilevel meta-analysis of single-subject experimental design studies. *Evidence-Based Communication Assessment and Intervention*, *2*, 142–158.

Ylvisaker, M., Turkstra, L., Coehlo, C., Yorkston, K., Kennedy, M., Moore-Sohlberg, M., & Avery, J. (2007). Behavioural interventions for children and adults with behavior disorders after TBI: A systematic review of the evidence. *Brain Injury*, *21*, 769–805.

DOI: 10.1002/bin