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Applied behavior analysis measurement, assessment, and treatment of sleep and sleep-related problems

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This discussion article considers applied behavior analysis measurement, assessment, and treatment of sleep and sleep-related problems among infants, children, and youth who are typically developing and have neurodevelopmental disabilities. Measurement has concentrated on designing practitioner-implemented methods and improving fidelity of data recording through sleep-monitoring instrumentation. The emphasis of assessment is identifying antecedent and consequence variables that promote sleep and evoke and maintain sleep-related problems. Treatment research has evaluated several effective interventions for problems such as delayed sleep-onset, night and early morning waking, bedtime resistance, and unwanted co-sleeping. Early and contemporary applied behavior analysis research is reviewed relative to function-based treatment formulation, intervention integrity, social validity, and research-to-practice translation.

Key words: applied behavior analysis, behavioral treatment, sleep assessment, sleep-related problems

Applied behavior analysis (ABA) research in the area of sleep and sleep-related problems has concentrated on infants, children, and youth that are both typically developing and who have neurodevelopmental disabilities (Durand, 2014a; Luiselli, 2016; Mindell et al., 2006). Notably, there are age-specific guidelines and recommendations for desirable sleep duration and sleep quality (Paruthi et al., 2016) but many infants, children, and youth experience difficulty initiating and maintaining sleep. Unfortunately, care providers may be instructed to implement interventions that are not empirically supported or to give medications that have no benefit (Owens et al., 2003). One contribution of ABA research, discussed herein, has been dissemination of evidence-based practitioner guides for enhancing sleep and eliminating sleep-related problems (Durand, 2014b; Friman, 2005; Mindell, 2005).

There are many negative consequences when infants, children, and youth sleep poorly, including health risks (Colton & Altevogt, 2006), emotional dysregulation (Hysing et al., 2016), impaired neurocognitive functioning (O'Brien, 2013), parenting stress (Meltzer & Mindell, 2007), and occurrence of daytime challenging behavior (Eshbaugh et al., 2004). As well, O'Reilly (1995) and Kennedy and Meyer (1996) demonstrated that escape-motivated problem behavior occurred more frequently for some individuals during demand conditions when they were sleep deprived the day before. Similarly, Reed et al. (2005) reported a relationship between food acceptance, pre-meal sleep, and sleep disruption in a young child with health complications. Hence, effective sleep intervention represents a two-pronged process intended to improve sleep and in doing so, positively affect learning, health, general deportment, and quality of life of the persons treated and their care providers.

Commenting on the early development of ABA sleep research, Jin et al. (2013) identified several limitations and topics in need of further study. First, behavioral research should strive to

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incorporate objective measurement systems beyond narrative report in sleep diaries and completion of self-report questionnaires (Sadeh, 2015). Second, meaningful research-to-practice translation requires that parents and other care providers are able to implement measurement, assessment, and treatment procedures capably and with good integrity. A related concern is that some but not many of the early sleep studies included social validity assessments of intervention acceptability and approval. Finally, functional assessment of the conditions that contribute to desirable sleep and sleep-related problems should be a necessary element of research and clinical practice to inform and individualize treatment.

This discussion article is a selective presentation of ABA measurement, assessment, and treatment of sleep and sleep-related problems and not a systematic review or meta-analysis of the extensive peer-reviewed literature. The article focuses on research conducted primarily with children, referencing seminal studies, but concentrating on contemporary publications from the period 2014 to 2020 and summarizing several key topics that have emerged.

Common Sleep Concerns

Between 20-30% of typically developing infants and children experience sleep problems (Johnson & McMahon, 2008; Mindell et al., 2009). Higher prevalence rates between 50-80% have been reported among children who have neurodevelopmental disabilities such as autism spectrum disorder (ASD) (Kotagal & Broomal, 2012). One of the most common sleep problems, *delayed sleep-onset*, occurs when children do not fall asleep within a reasonable time after being put to bed. In some cases, children remain awake quietly in their beds or play with preferred objects but typically call out and exit the bedroom to interact with care providers. The problem of *night waking* occurs as children falling asleep at bedtime but waking up multiple times during the night. This situation results in fewer hours of continuous sleep and a fragmented sleep–wake cycle. Third, children who demonstrate *early-morning waking* sleep continuously for many hours after going to bed, wake-up before getting a full night's sleep (e.g., 3:30-4:00 am), and remain awake thereafter. The frequently encountered problem of *bedtime resistance* represents behaviors such as crying, screaming, environmental disruption, tantrums, and aggression from children when care providers direct, prompt, and guide them to bed. Some additional concerns include children being unable to fall asleep without access to particular tangible items and activities (so called, *sleep dependencies*) and who regularly sleep in their parents' bed (*unwanted co-sleeping*). Co-occurring sleep problems are also typical, for example, bedtime resistance in children who have difficulty falling sleep and children who wake up early in the morning.

There is consensus within the professional community that difficulty initiating and maintaining sleep in childhood "involves a multifactorial pathophysiological mechanism and represents a complex combination of biological, circadian, and neurodevelopmental factors that are influenced by, but not solely attributable to environmental and behavioral variables" (Mindell et al., 2006, p. 1264). In illustration, delayed sleep-onset may be the result of a child not being developmentally ready to fall asleep (i.e., a lack of physiological sleep pressure), over-stimulating conditions in the bedroom, inconsistent bedtime routines, and consumption of caffeine-laden foods and beverages before going to bed. Consequences maintaining delayed sleep-onset include children receiving social attention from care providers, engaging in sleep-competing behaviors (e.g., playing video games, listening to music), and escaping the requirement of sleeping alone through co-sleeping arrangements. Accurately measuring sleep and sleep-related problems and assessing evoking and maintaining variables, discussed below, are critical components of contemporary ABA research and practice.

Measurement

Sleep questionnaires are used frequently to identify sleep concerns and measure the effects of interventions (Abel et al., 2017; Sadeh, 2015; Sanberg et al., 2018). Examples include the *Family Inventory of Sleep Habits* (FISH; Malow et al., 2009), *Pediatric Sleep Questionnaire* (PSQ; Chevrin et al., 2000), *Behavioral Evaluation of Disorders of Sleep* (BEDS; Schreck et al., 2003), and *Children's Sleep Habits Questionnaire* (CSHQ; Owens et al., 2000). The content of sleep questionnaires varies but generally seeks information from respondents about medical, environmental, and interpersonal factors that promote sleep and contribute to sleep problems. As subjective pediatric sleep measures (Lewandowski et al., 2011), responses to sleep questionnaires may be subject to biases and should be verified through direct observation.

Sleep diaries require that care providers record narrative entries and behavior data throughout the day. For example, in a sleep intervention study with children who had ASD, Sanberg et al. (2018) designed a sleep diary in which parents documented measures such as latency to sleep-onset, duration of total sleep, frequency of night waking, and occurrence of unwanted co-sleeping. Sleep efficiency metrics were converted from the sleep diary recordings as outcome measures. Like sleep questionnaires, sleep diaries often reflect the subjective impressions of informants and should be periodically assessed for interrater agreement (van Deurs et al., 2020) and compared to other information sources.

Real-time direct measurement consists of researchers, practitioners, and care providers recording sleep behaviors via child observations in treatment settings, homes, and other living arrangements. Frequency data of calling out and leaving the bedroom (Freeman, 2006), audio recordings of crying and vocal disruption (Moore et al., 2007), and occurrence intervals of sleep and wakefulness (O'Reilly et al., 2004; Piazza & Fisher, 1991) exemplify some of the direct measurement methods conducted in ABA research. As noted, sleep diaries are sometimes used to collect these data but more often, observers record frequency, duration, and interval measures on precoded forms. For example, Luiselli et al. (2005) created a sleep recording protocol that was sequenced in consecutive 30-min intervals starting at 7:00 pm each day through 7:00 am the next day. Care providers at 16 community group homes observed adults with intellectual and developmental disabilities in their bedrooms at the conclusion of each interval and recorded whether they were asleep, awake, out of bed, or disruptive. The data were then computed as nightly total percentage measures for every adult.

Advances in sleep measurement have emphasized different systems of remote observation and data collection through videosomnography (i.e., time-lapse video recording), actigraphy (i.e., automated detection of motor movements) and polysomnography (i.e., monitoring of biophysiological activity) (Mannion & Leader, 2014; Sadeh, 2015). Jin et al. (2013) used a high-definition camera with infrared illumination to record sleep, delayed sleep-onset, and night waking in two children who were typically developing (7-9 years old) and one child who had ASD (9 years old). Parents were instructed to activate a bedroom camcorder after putting their children to bed and to turn it off upon waking in the morning. The researchers conducted direct measurement from the video recordings (i.e., duration and time-sampling) to quantify sleep-onset delay, sleep-interfering behavior, night waking, and hours of sleep. There was high interobserver agreement among the video-recorded sleep measures (M ranges = 93-100%) and satisfactory correspondence between the video-recorded sleep measures and parent reported sleep diaries. Practical considerations when adopting this method of direct measurement are that video recording may be too intrusive for some families and technical difficulties may be experienced such as parents forgetting to plug in the camcorder and to turn on the night-shot mode. Nevertheless, Jin et al. (2013) advised that at minimum, video recording can be adopted initially to calibrate parent measurement through sleep diaries and incorporated to evaluate the effects of behavioral sleep intervention. Videosomnography has since been used efficiently in several ABA sleep intervention studies (Lichtblau et al., 2018; McLay et al., 2019; van Deurs et al., 2019).

Lesser et al. (2019) measured sleep disturbance in three children with ASD (3-4 years old) in their homes with a motion-detection camera that was connected to a laptop computer with applicable software settings. The camera simultaneously recorded continuous video and motion-detection throughout the night. Although the motion-detection camera underestimated total sleep disturbance due to the size of the detection window, it accurately measured latency to sleep-onset and was more efficient than extracting sleep data from the continuous video. As yet, this motion-detection system has not been employed in ABA sleep treatment research. Further, three facets of Lesser et al. have research-to-practice implications, namely (a) cost (approximately $2,400 for the system), (b) personnel resources for operating equipment, and (c) utility of motion-detection in assessing intervention integrity.

Another approach to sleep motion-detection, reported by Sanberg et al. (2018), had three children with ASD (4-8 years old) wear a small sensor about the size of a wristwatch on their ankle. The sensor recorded movement continuously during sleep, producing activity data that quantified sleep–wake cycles via a scoring algorithm. The actigraphy measurement was sensitive to intervention that reduced the children's time falling asleep and night waking, as well as longer duration of total sleep. Although not encountered in Sanberg et al., some children may not tolerate wearing a sensor device and require compliance training to ensure they do not remove or damage it.

Despite advancements in remote sleep recording instrumentation, some settings such as residential schools and group homes must rely on direct measurement that estimates sleep from care provider observations. Shlesinger et al. (2020) described a computer-assisted sleep monitoring system intended to improve measurement integrity among care providers serving residential students with ASD and related neurodevelopmental disabilities (8-21 years old). Care providers briefly observed students in their bedrooms every 15-30 min and entered one of 18 sleep codes (e.g., sleeping, in bed awake, out of bed) into a data recording application on a laptop computer. The sleep recordings with supplementary notes were electronically stored and computed throughout the evening. The sleep monitoring system also sent an urgent text message to an overnight supervisor if care providers had not entered sleep data within a prescribed window of time per observation interval. Supervisors and program administrators received next-day reports and visual sleep charts of every student in order to evaluate trends, isolate problems, and recommend interventions if needed. Shlesinger et al. (2020) documented average implementation integrity of the system at 91% among care providers over a 4-year period.

Assessment

A sleep questionnaire such as the FISH (Malow et al., 2009) can be used to identify influences on child sleep problems but the instrument was not designed for the purpose of functional behavioral assessment (FBA). A specific FBA instrument such as the *Questions About Behavioral Function* (QABF; Matson & Vollmer, 1995) has been incorporated in ABA sleep research, though infrequently (van Deurs et al., 2019; van Deurs et al., 2020).

The *Sleep Assessment and Treatment Tool* (SATT; Hanley, 2005) is an open-ended functional assessment interview conducted with care providers targeting several variables that may be responsible for children's sleep problems. The SATT includes questions about the type and history of presenting sleep problems, desirable sleep goals, and conditions in effect when a child resists bedtime, displays sleep-interfering behavior (e.g., getting out of bed, exiting the bedroom), takes longer than 15 min to fall asleep, and wakes up in the middle of the night or early in the morning. Other information documented in the SATT is a child's sleep schedule, pre-bedtime routines, ambient sleep environment, and any preferred objects taken to bed. Depending on the results of functional assessment, the SATT includes suggestions of one or more interventions that researchers and care providers can choose.

Several studies have featured the SATT in sleep intervention research with children and adolescents who were typically developing or had ASD (Delemere & Dounavi, 2018; Jin et al., 2013; McLay et al., 2019; van Deurs et al., 2019, 2020). In all cases, the SATT informed effective treatments for delayed sleep onset, night and early morning waking, bedtime resistance, night tantrums, and unwanted co-sleeping. On a clinical level, the value of the SATT and similar interview formats is isolating the vast and usually co-occurring number of antecedent and consequence variables that can interfere with sleep and maintain sleep problems. For example, studies with the SATT reported that playing with books, magazines, and paper while in bed, interacting with siblings, engaging in motor and vocal stereotypy, listening to music, playing with electronic devices, repeatedly asking questions to parents, accessing food, intrusive noise and light, and physical comforting were functional variables subsequently addressed through multiprocedure interventions.

Treatment

This section describes the most frequently reported ABA sleep interventions, including several seminal studies and contemporary research conducted in the past 6 years. Note that most of the interventions combined multiple procedures and were effective with more than one sleep problem.

Faded Bedtime With and Without Response Cost

In treating delayed sleep-onset among four children with intellectual and developmental disabilities (3-19 years old) on a specialized inpatient unit, Piazza and Fisher (1991) first documented the average time each child fell asleep, then implemented a faded bedtime protocol by setting an initial bedtime that was 30 min later. Each evening, time to bed was adjusted 30 min ahead or back depending on the latency to sleep-onset the night before. If the children had not fallen asleep within 15 min of their scheduled bedtime, unit staff kept them out of their rooms for 60 min (response cost) before repeating the faded bedtime protocol. Compared to baseline conditions, this combination of procedures increased duration of appropriate sleep by the four children and three of them had fewer periods of daytime sleep and incidents of night waking.

Ashbaugh and Peck (1998) replicated the faded bedtime and response cost intervention for delayed sleep-onset with a 2-year old typically developing child in her family home. Baseline measurement revealed that the child stayed awake after her parents put her to bed, usually at 9:00 pm, and on average did not fall asleep until 10:30 pm. Faded bedtime started at 11:00 pm and if the child was sleeping 15 min later, her scheduled bedtime was 30 min earlier the following night. When the child was not asleep within 15 min, the next night's scheduled bedtime was 30 min later. The response cost component of treatment, similar to Piazza and Fisher (1991), had the parents keep the child awake, but for 30 rather than 60 min contingent on delayed sleep-onset. The faded bedtime plus response cost intervention decreased delayed sleep-onset and the child established a more regular sleep–wake cycle.

Several replications and adaptations of faded bedtime were conducted in recent research. Sanberg et al. (2018) intervened with three children who had ASD (4-8 years old) with faded bedtime and response cost in addition to their parents (a) maintaining a consistent wake time each morning regardless of sleep duration the night before, (b) preventing daytime napping unless otherwise designated for the child, and (c) withholding attention contingent on disruptive behaviors at and during bedtime. This combination of procedures not only reduced delayed sleep onset in all of the children but also reduced night waking, bedtime resistance, and unwanted co-sleeping as well.

Delemere and Dounavi (2018) compared the effects of bedtime fading without response cost to positive bedtime routines on delayed sleep onset, frequency and duration of night waking, and total sleep duration of six children with ASD (2-7 years old). Three of the six children received faded bedtime without response cost in which parents began by placing them in bed 30 min after their average sleep-onset time recorded before intervention. When the children demonstrated sleep-onset latency under 15 min, bedtime was faded 15 min earlier the next night or moved 30 min later if time to sleep-onset exceeded 15 min. Absent response cost, parents verbally prompted their child to bed contingent on night waking. With the positive bedtime routines intervention, parents selected a desirable bedtime for their child, implemented sleep readiness activities 30 min before going to bed (e.g., reading stories, washing, dressing), and avoided interactions that might evoke challenging behavior. Both interventions decreased delayed sleep-onset although faded bedtime without response cost was more effective at increasing total sleep duration.

Finally, Luiselli et al. (2020) extended faded bedtime without response cost to an 18-year old woman who had ASD and lived in a group home at a residential school. Preceding intervention, she averaged 2.3 hr to fall asleep and only 6.7 hr of continuous sleep each night. From baseline sleep-onset data, intervention began with an 11:00 pm bedtime that was gradually faded to 10:30 pm, then 10:00 pm, following multiple consecutive nights of reduced time falling asleep. The woman was kept busy during the hours before bedtime by participating in preferred educational activities with group home care providers but not as a response cost consequence. By the conclusion of intervention, latency to sleep-onset was less than 30 min and the participant averaged 8.4 hr of continuous sleep each night.

Differential Attention

O'Reilly et al. (2004) conducted intervention with a 5-year-old child who had severe intellectual disabilities and difficulty settling herself after her parents put her to bed, repeatedly exiting her bedroom, and usually sleeping less than 6 hr each night. A choice-assessment before intervention found that the child preferred to interact with her mother when she left her bedroom. The first phase of intervention consisted of scheduling a standard pre-bedtime routine with the child (e.g., snack, dressing in pajamas, watching a video), putting her to bed consistently at 8:00 pm, and immediately returning her to the bedroom upon leaving. The scheduling intervention was ineffective when implemented in isolation but reduced delayed sleep-onset and bedroom exits when combined with fixed-time social attention from the child's mother every 5 min until she fell asleep.

Friman et al. (1999) developed the *Bedtime Pass Program* (BPP) as a parent-implemented intervention consisting of differential reinforcement and social extinction. Two typically developing children, ages 3 and 10 years, received a card (pass) they could exchange for one "free trip" from their bedroom or one parent visit before being returned to bed. Further bedtime resistance was "ignored" by parents withholding attention. This easily implemented and highly rated intervention by parents eliminated calling out and leaving the bedroom after the children were bid "good night." Moore et al. (2007) later evaluated the BPP in a randomized controlled trial with 19 typically developing children (3-6 years old) whose bedtime resistance consisted of crying out and leaving the bedroom after being put to bed. Parents in the BPP group (*N* = 9) were instructed to set a standard bedtime for their child, present the pass for one "free trip" out of the bedroom or requested parent visit, and withhold reactions to subsequent attention-seeking behavior. Compared to the control group (*N* = 10), the children who received the BPP left their bedrooms significantly less often and required significantly less time to quiet after bedtime. Another meaningful finding was the absence of an extinction burst associated with intervention (Lerman et al., 1999). Of note, the extinction component of the BPP would have to be adjusted if a child's bedtime resistance was maintained by access to tangible items and activities or negatively reinforced by social isolation. Also, the BPP has not been evaluated in research with children who have intellectual and neurodevelopmental disabilities.

Freeman (2006) replicated the effects of the BPP on bedtime resistance of four typically developing 3-year old children and also performed a component analysis of the intervention in two cases. The frequency of bedtime resistance was higher when parents used the pass alone without accompanying social extinction, suggesting that both procedures may be necessary for optimal effectiveness. Similar to Moore et al. (2007), extinction bursts were not encountered with the BPP.

The *Excuse Me Drill* (EMD), reported by Kuhn et al. (2019) "targets adaptive skills by teaching caregivers to strategically provide positive attention when children practice sleep compatible bedtime behaviors…while ignoring disruptive behavior" (p. 3). Care providers implemented the EMD by (a) placing a child in bed following an established routine, (b) excusing themselves from the bedroom for a few seconds, (c) returning to praise behaviors such as remaining quiet, staying in bed, and preparing for sleep, and (d) gradually increasing duration of "excuse me" trips until the child was able to fall asleep independently. Disruptive behavior was ignored and the EMD was repeated when children were calm. Kuhn et al. found that the program reduced latency to sleep onset and decreased crying, screaming, leaving the bedroom, and aggression of three typically developing children (2-7 years old) and one child with ASD (7 years old), although extinction bursts were apparent in all cases.

Multiprocedure Packages

Jin et al. (2013) interviewed the parents of three children using the SATT in order to pinpoint specific sleep concerns, contributory environmental variables, and acceptable interventions. From this information, parents were trained to implement procedures intended to enhance establishing operations and discriminative stimuli associated with falling asleep and eliminate the consequences maintaining sleep-interfering behavior. Problems of delayed sleep onset, sleep disruption, and night waking were treated successfully through function-based interventions such as adjusting sleep schedules (faded bedtime), taking away sleep-disruptive objects and activities, terminating over-stimulating pre-bedtime routines, introducing relaxing transition-to-bed activities, and removing behavior-contingent access to attention and tangible items.

McLay et al. (2019) also used the SATT with parents of seven children who had ASD (2-4 years old) and a primary presenting problem of unwanted co-sleeping that usually occurred subsequent to delayed sleep-onset and night waking. Functional assessment revealed that co-sleeping resulted in positive reinforcement (social attention, preferred activities, physical comforting) and negative reinforcement when parents removed the children from their bedrooms and did not require them to sleep alone. Taking a lengthy time to fall asleep also set the occasion for problem behavior and eventual co-sleeping. Parent treatment objectives were to facilitate rapid sleep-onset, maintain prolonged sleep, decrease sleep-interfering behavior, and eliminate unwanted co-sleeping. Different combinations of function-based interventions were implemented including narrative and photographic representation of bedtime routines (social stories), social extinction, presence of a clock as a discriminative stimulus for sleep and morning waking, and positive reinforcement contingent on children sleeping in their own bed throughout the night. The multiprocedure packages eliminated unwanted co-sleeping in all of the children and also reduced sleep-onset delay and night waking in several cases.

Another evaluation of FBA-informed treatment of sleep problems was conducted by van Deurs et al. (2019) with three older children who had ASD (9-14 years). The results of parent interviews from the SATT and QABF, sleep diaries, and analysis of night video recordings suggested that problems of delayed sleep-onset and night and early-morning waking were evoked and maintained by several antecedent and consequence variables identified as inconsistent sleep–wake cycles, daytime sleeping, stimulating pre-bedtime routines, sleep environment discomfort, access to electronic devices, exposure to bright light, and social reinforcement of sleep-interfering behavior. Similar to Jin et al. (2013) and McLay et al. (2019), each child was effectively treated with packaged interventions that were matched to the functional determinants of their sleep problems, specifically faded bedtime, scheduled bedtime routines, presence of stimuli associated with going to sleep and waking up, access to sleep-conducive objects at bedtime, provision of sleep-contingent reinforcement, and social extinction.

Treatment research conducted by Lichtblau et al. (2018) evaluated a remote monitoring and telehealth-delivered intervention for a 3-year old girl with ASD who pulled (trichotillomania) and ingested (trichophagia) her hair. Measurement of head touches, mouth touches, and sleep duration consisted of interval recording from night vision videos captured from a bedroom camera. The girl's care providers received remote coaching, initially instructing them to set a standard bedtime, remove bedroom distractions, and present unique discriminative stimuli (e.g., pillows, blanket) in the sleeping environment. During a subsequent phase, they administered Melatonin at bedtime, starting at 1 mg and gradually increased to a terminal 4 mg dose. This biobehavioral treatment was later supplemented by having care providers wake the girl at a regular time in the morning and prevent her from sleeping during the day. Although functional control of the full treatment was not demonstrated, Melatonin was associated with decreased head and mouth touching and increased sleep duration. Notwithstanding this demonstration of a telehealth model of sleep treatment, the study was limited by the inability to assess procedural fidelity among the care providers.

Antecedent Control

Interventions composed primarily of antecedent control procedures have addressed several sleep problems. Thiele et al. (2001) treated a 17-year old boy with intellectual and developmental disabilities who displayed morning sleep waking disruption at a residential school. The boy woke up in the morning between 6:30-7:00 am, often crying, screaming, and injuring himself. A preintervention FBA suggested that sleep waking disruption was maintained by care providers speaking to and physically prompting the boy during his morning self-care routines. With intervention, one of several care providers the boy preferred greeted him immediately upon waking, conversed for several minutes about pleasurable topics, and ensured he was calm and ready before initiating the self-care routines. These procedures reduced and eliminated sleep waking disruption, possibly serving as an abolishing operation, and the effects maintained 9 months postintervention.

Friedman and Luiselli (2008) reported one of the few cases of behavioral intervention for excessive daytime sleepiness. The participant was a 13-year-old boy with ASD who slept during the day in his classroom when on breaks from instruction and under conditions of low supervision. His daytime sleep also appeared to interfere with him sleeping through the night. As an antecedent intervention directed at the situations commonly associated with daytime sleep, teachers removed a soft floor mat on which the boy slept, directed him to engage with stimulating objects and activities when he appeared drowsy, and increased social interactions with praise and physical contact (pats on the back) to further promote wakefulness. The intervention eliminated daytime sleeping and results maintained though a 6-month follow-up.

Scheduling positive bedtime routines is an antecedent intervention in which care providers present children with calming activities during a defined period before going to bed. It is sometimes accompanied by soothing stimulation and objects that facilitate sleep (Mindell & Williamson, 2018). There is a large body of research showing that positive bedtime routines can promote earlier bedtimes, shorten latency to sleep onset, decrease night waking, and improve duration of total sleep (Mindell et al., 2015). Most of these interventions implement multiple procedures simultaneously, as demonstrated in a study by Knight and Johnson (2014) who reduced the delayed sleep onset and night waking of three children with ASD (4-5 years old) by combining fixed daily bedtime and wake-up schedules, positive bedtime routines, white noise, and social extinction. A recent exception is a case report of a 9-year old child with ASD showing the cumulative positive effects of white noise, white noise plus relaxation training, and white noise, relaxation training, plus eliminating sleep-interfering behaviors at bedtime for improving latency to sleep onset and hours of continuous sleep (van Deurs et al., 2020).

Summary and Research-to-Practice Implications

Applied behavior analysis measurement, assessment, and treatment of sleep and sleep-related problems continues to evolve with infants, children, and youth who are typically developing and have neurodevelopmental disabilities. Compared to earlier studies, current research has emphasized functional assessment in order to formulate interventions based on the many antecedent and consequence variables associated with sleep enhancement and sleep disruption (Jin et al., 2013; McLay et al., 2017; McLay et al., 2019; Sanberg et al., 2018; van Deurs et al., 2019). It is reasonable to conclude that assessment-informed sleep interventions will be more effective than treatment procedures that are topography-focused and selected arbitrarily without reference to controlling variables (Blampied, 2013). Both component analyses of the procedures comprising treatment packages and comparison of methods in the context of alternating treatment designs (Kazdin, 2011) should be research priorities.

There is a solid conceptual basis for each of the behavioral interventions discussed herein. Bedtime fading induces sleep deprivation as a physiological state conducive to falling asleep within a classical conditioning framework (Piazza & Fisher, 1991). Differential attention involves rearranging the socially reinforcing consequences of sleep problems to follow sleep-compatible behavior (Kuhn et al., 2019). Differential attention may also function as an abolishing operation in an intervention such as the BPP (Friman et al., 1999) or when care providers present fixed-time praise and approval to a child whose bedtime resistance is socially motivated (O'Reilly et al., 2004). The evidence that many sleep problems have social-positive, social-negative, and automatic reinforcement functions is the rationale for treatment packages that match procedures to controlling variables (McLay et al., 2019; van Deurs et al., 2019). Relative to antecedent control interventions, the mechanism of change consists of manipulating the discriminative stimuli and motivating operations that increase the reinforcing value of initiating and maintaining sleep (Jin et al., 2013).

Four other elements of behavioral sleep intervention are reflected in contemporary research. Measurement via video and motion-detection sleep recordings has advanced the quality and integrity of methods commonly employed in research and on a clinical level. There is now sufficient evidence for including automated sleep monitoring in homes and other settings given the emergence of remote and telehealth models of service delivery (Luiselli & Fischer, 2016). Future research should continue to compare the accuracy of different measurement approaches as well as practical considerations related to cost, procedural efficiency, integrity, and sensitivity to sleep-changing interventions (Lesser et al., 2019; Sanberg et al., 2018).

Virtually all behavioral sleep research has evaluated multiprocedure treatment packages, placing a premium on intervention integrity given implementation demands among care providers and the lack of in-person supervision they receive during late-evening, overnight, and early-morning hours. It is encouraging that several studies have addressed intervention integrity with methods such as observing parent behavior from video recordings (Jin et al., 2013) and comparing sleep diaries, video footage, and therapist contact notes against behaviorally anchored treatment checklists (McLay et al., 2019; van Deurs et al., 2019). Of course, establishing exemplary intervention integrity is a prerequisite for accurately evaluating the effects of behavioral sleep interventions and should be emphasized during care provider training and consultation. To promote intervention integrity or when less than desirable intervention integrity is encountered, behavior analysts should emphasize the most critical components of treatment, use behavioral skills training, conduct post-intervention booster training, and gradually fade contact with care providers (Jin et al., 2013; McLay et al., 2019).

Social validity is fundamental to applied behavior analysis (Wolf, 1978) and has been assessed in sleep research through parent and care provider questionnaires with questions related to the acceptance, satisfaction, and helpfulness of interventions (Jin et al., 2013), asking whether they would recommend procedures to other practitioners (Shlesinger et al., 2020), and having them complete rating instruments such as the *Treatment Acceptability Rating Form-Revised* (McLay et al., 2019; Reimers et al., 1992) and *Intervention Rating Profile-15* (Martens et al., 1985). Behavioral sleep assessment and treatment was well received and positively rated in this research although in some cases, care providers "perceived the interventions to require a great deal of effort and time to implement" (McLay et al., 2019, p. 14). One strategy to mitigate negative reactions is to conduct social validity assessment preceding treatment to verify that intervention objectives and methods are suitable to particular settings and viewed by care providers as being practical, efficient, and reasonable (Durand, 2014b; Jin et al., 2013).

Maintenance of behavioral treatment that improves sleep quality has been reported 3-14 weeks postintervention (Lichtblau et al., 2018; Luiselli et al., 2020; Piazza &

Fisher, 1991; van Deurs et al., 2019) and as long as 9-12 months later (O'Reilly et al., 2004; Thiele et al., 2001). In some cases, follow-up results were measured while components of treatment remained in effect or for a period of time after sleep problems had resolved and treatment was discontinued. Behavior analysts have long been advised about methods to promote maintenance (Stokes & Baer, 1977) and they apply similarly to sleep interventions. Accordingly, treatment should be implemented under the conditions expected to be present in the postintervention setting. Attention should be paid to potential barriers or complicating situations that risk recurrence of sleep problems previously treated successfully. Having extended contact between care providers and service professionals can support maintenance through follow-up assessment and additional treatment support and recommendations. Finally, telehealth and teleconsultation models can contribute to desirable maintenance outcomes (Lichtblau et al., 2018; Tsami et al., 2019) and are being delivered with greater regularity in ABA sleep measurement, assessment, and treatment research (McLay et al., 2020).

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