Evaluating the Relationship Between Sleep and Problem Behavior in Children with Disabilities

Mindy C. Scheithauer • Jennifer Zarcone

Published online: 30 January 2015

© Association for Behavior Analysis International 2015

Problem behaviors, such as aggression, self-injury, and disruption, are common reasons for referrals for individuals with developmental and intellectual disabilities (Emerson et al. 2001; Murphy et al. 2009). Several studies using parental report indicate that children with problem behavior are also more likely to have sleep difficulties (e.g., Mazurek et al. 2013; Rzepecka et al. 2011), while others suggest that the two domains are not correlated (Dominick et al. 2007). There has also been support from a direct observation study suggesting that individuals who exhibit problem behavior have more sleep difficulties when compared to national norms (Piazza et al. 1996), but these findings are correlational in nature and do not provide information about a temporal relationship. Thus, it is unclear from current research whether sleep difficulties and problem behavior vary together (e.g., whether behavior is worse on days following low sleep) or whether they are temporally unrelated (Brylewski and Wiggs 1999).

In evaluating the relationship between problem behavior and sleep, it is helpful to consider the three-term operant model of antecedents, behaviors, and consequences. Motivating operations are defined as an antecedent event that alters the value of a consequence. One type of motivating operation, an establishing operation, temporarily increases the value of a

reinforcer and evokes behaviors that have historically resulted in that reinforcer (Laraway et al. 2003; Michael 1982). Sleep has been identified as a potential motivating operation for problem behavior, especially behaviors maintained by negative reinforcement (e.g., Langhorne et al. 2013). In other words, sleep deprivation (or fatigue) may increase the reinforcing value of escape from demands and make problem behavior maintained by escape more likely to occur when the child has limited sleep. In a practical example, a child may find math work more aversive if he/she is tired, resulting in an increased reinforcement value of escape from math. If the child has historically escaped math work by engaging in aggression, he/she is more likely to engage in this aggression when he/she is tired.

There have been a few studies that use direct observation to demonstrate a temporal relationship between sleep and problem behavior and provide support for the idea that lack of sleep might serve as a motivating operation for problem behavior. Studies using pharmacological treatments to improve sleep have found that daytime problem behavior decreases with sleep improvement (Eshbaugh et al. 2004; Sovner et al. 1999). Other support for a temporal relationship between sleep and problem behavior arises from studies evaluating the effects that sleep might have on functional analyses (FAs) outcomes. FAs are usually conducted in a therapeutic setting to determine environmental variables that might maintain an individual's problem behavior. A therapist manipulates the environmental antecedents (e.g., presents demands, appears busy or unavailable for attention, removes a preferred item) and the consequences for the target behaviors (e.g., provides escape from demands, gives attention, or returns the preferred item) to determine under what conditions problem behavior is most likely (see Iwata et al. (1982, 1994) for a complete description of functional analyses procedures). These FA studies largely suggest that individuals who engage in problem behavior to escape demands have higher rates of

M. C. Scheithauer • J. Zarcone
Johns Hopkins School of Medicine, Kennedy Krieger Institute, 707
North Broadway, Baltimore, MD 21205, USA

M. C. Scheithauer (✉)
Marcus Autism Center, 1920 Briarcliff Rd NE, Atlanta, GA 30329,
USA
e-mail: mindysche@gmail.com

Present Address:

M. C. Scheithauer
Emory University School of Medicine, 1920 Briarcliff Rd NE,
Atlanta, GA 30329, USA

problem behaviors in demand settings after nights with deprived sleep (Kennedy and Meyer 1996; O'Reilly 1995) and when daytime sleep is limited (O'Reilly and Lancioni 2000). Although most research has looked at sleep in the context of escape-maintained problem behavior, Horner et al. (1997) found that a participant's problem behavior also increased after nights with low sleep in context with denied access to a preferred item. In addition, this participant's problem behavior diminished when he was provided a nap on days following low sleep. Contrary to these findings, in at least one study, sleep deprivation did not appear to be functionally related to problem behavior (DeLeon et al. 2004).

Although research using indirect measures suggests that individuals with problem behavior are more likely to have sleep challenges, few studies have evaluated the potential temporal relationship between sleep and problem behavior using direct observation data collection. The studies that have used observational measurement suggest that sleep might serve as a motivating operation for reinforcement maintaining problem behavior, but several of these participants were selected based on prior assumptions about the relationship between sleep and problem behavior (e.g., Kennedy and Meyer 1996; O'Reilly 1995; O'Reilly and Lancioni 2000) limiting the generalizability of these findings. In addition, with the exception of one study evaluating behavior maintained by access to tangibles, this relationship has primarily been demonstrated with negatively reinforced problem behavior and with a limited number of individuals. It is unclear whether these results can be generalized to more individuals with problem behavior and whether the motivating operation theory holds true for other types of reinforcement that might maintain problem behavior (e.g., to obtain attention or toys).

The current study has two main aims. The first aim is to determine if prior research suggesting that there is a temporal relationship between low sleep and problem behavior can be generalized to a larger sample which has not been selected for a specific function of problem behavior or because of a preexisting hypothesis about sleep impacting problem behavior. The second aim is to determine if low sleep has differential effects on problem behavior during times with academic demands (with escape contingent on problem behavior) and if the effects of low sleep are different dependent on whether escape served as a functional reinforcer for problem behavior (identified through a FA).

Materials and Method

Participants

Participants were individuals referred to an inpatient unit for the assessment and treatment of severe problem behavior. Caregivers of all participants provided consent to treatment

on the inpatient unit, and all data described were collected as part of routine clinical treatment. Data were deidentified prior to the analysis to protect confidentiality. The unit specializes in serving individuals with intellectual disabilities and severe self-injury, aggression, property destruction, and other challenging behaviors. Data were selected from electronic-archival files of individuals who were admitted to the unit between 1985 and 2013. Files were alphabetically selected and evaluated until at least 20 participants were identified that met the inclusion criteria.

The experimenter searched each electronic archived record for the presence of nightly data for sleep (with data recorded every 30 min) and daily data for problem behavior (with enough information to compute responses per hour) collected while the participant was in the pretreatment portion of his or her admission (described below). In total, 224 participant files were evaluated; 66 of these were not included due to missing data or data in a format not compatible with evaluation (e.g., paper and pencil graphs without raw data). The remaining 158 participant files included daily rates of combined problem behavior as well as nightly sleep records. This sample had a mean age of 12.49 years (range 3 to 33) and was predominately male (72.15 %). As noted above, the records that were reviewed came from the initial weeks of a participants' admission, and the majority of participants were admitted on psychotropic medications. During this period, it was standard practice for the supervising psychiatrists to attempt to decrease and/or eliminate any medications that do not appear to have any positive behavioral effects (Wachtel and Hagopian 2006). As this study was an archival review and this information was only available for a portion of the patients, the effects of changes in medication on sleep data were not systematically evaluated.

The experimenter analyzed each participant's sleep record to determine if he/she had significant sleep variability (defined as 20 % of nights with 2 h less than recommended for the individual's age; see procedures section for details). In total, 22 participants met the requirements for significant sleep variability and were included in the rest of the analyses. The majority of individuals in this group (86.36 %) were diagnosed with developmental delays, and 81.82 % of participants were diagnosed with an intellectual disability of varying degrees. All participants had multiple psychological diagnoses (see Table 1 for specific demographics of this group and Table 2 for specific sleep information).

Measurement and Interobserver Agreement

On the inpatient unit, standard training procedures for all direct care staff who served as data collectors for the study included the following: 1 week of classroom training and evaluation of data collection and unit procedures, 1–2 weeks of in-person training in which they shadowed another staff

Table 1 Demographics and FA outcome for participants included in the analysis

No.	Age	Gender	Diagnoses	Function(s)
001	12	F	Profound ID, CP	Attention, tangible
002	8	M	Severe ID, AD, DBD, ADHD,	Attention, demand, tangible
003	17	F	Severe ID, AD	Automatic, tangible
004	7	M	ID (unspecified), AD, SMD, developmental speech D/O, other medical	Automatic
005	9	M	Moderate ID, AD	Tangible, attention
006	3	F	ID (unspecified), SMD, CP, other medical	Automatic
007	9	M	PDD, SMD, DBD	Tangible
008	14	M	AD, DBD, other medical	Undifferentiated
009	16	M	ID (unspecified), PDD	Demand
010	8	M	Severe ID, AD, DBD, CP	Attention
011	15	M	ID (unspecified), AD, DBD, mood disorder NOS, anxiety disorder NOS	Undifferentiated
012	8	F	Severe ID, SMD, CP, other medical	Automatic
013	19	F	Profound ID, AD, mood disorder	Undifferentiated
014	7	M	Moderate-to-severe ID, AD	Demand, tangible
015	16	M	Mild ID, AD, SMD, DBD, bipolar disorder	Undifferentiated
016	6	F	ID (unspecified), AD, pica, feeding disorder	Attention, demand, tangible
017	9	M	ID (unspecified), AD, SMD, DBD, mood disorder NOS	Attention, demand, tangible
018	10	M	ID (unspecified), AD, DBD, other medical	Attention, demand, tangible
019	5	F	Profound ID, PDD, SMD, other medical	Attention, demand, tangible
020	10	M	AD, SMD, unspecified disturbance of conduct	Attention
021	12	M	AD, SMD, DBD	Attention
022	10	M	Moderate-to-severe ID, AD, ADHD, bipolar disorder, other medical	Attention, demand, tangible

ID intellectual disability, *AD* autistic disorder, *PDD* pervasive developmental disorder, *SMD* stereotypic movement disorder with self-injury, *DBD* disruptive behavior disorder, *CP* cerebral palsy, *ADHD* attention deficit hyperactivity disorder, *other medical* variety of genetic and medical conditions

person and ensured reliable data collection with a veteran staff member, and daily monitoring and feedback from supervisors on patient care and data collection fidelity.

For sleep data collection, a 30-min momentary time-sampling procedure was used. Sleep was measured by the direct care staff, who circled either a “W” or “S” to indicate if the client was awake or asleep. Participants were observed continuously throughout the night (from their scheduled bedtime until their scheduled awake time). If there was a question of whether the patient was awake or asleep, the observer would stand within 1 ft of the participant and whisper his/her name. If there was an absence of verbal or motor response (e.g., opening eyes, vocalizing), the data sheet was marked as asleep. If the participant responded or was clearly awake, the observer marked the data sheet as awake. Similar data systems have previously been used to evaluate sleep with individuals with severe problem behavior and have resulted in high interrater reliability (Piazza et al. 1996).

Data were then summarized using the intervals between the individual’s bedtime and standard unit wake time (7:30 a.m.). No daytime sleep was considered in the calculation. Bedtime was determined using developmental charts that indicated the appropriate hours of sleep given the individual’s age (Ferber

1985). The number of intervals marked as asleep during this time was divided in half to determine the number of hours the individual slept each night.

Interobserver agreement (IOA) was assessed by having a second independent observer score the participant at each 30-min interval as awake or asleep. An agreement was scored if both observers scored the participant as asleep or if both observers scored the participant as awake. A disagreement was scored if one observer scored awake and one observer scored asleep. IOA was calculated by dividing the agreements by the sum of the agreement plus disagreements and multiplying by 100. IOA was calculated for all participants for whom the secondary observers’ raw data was retrievable from our data archive; IOA was obtained for 15 of the participants (68.18 %). A mean of 38.04 % of nights (range 31.76 to 46.88 %) for each participant with data was compared for IOA. The mean IOA across participants was 98.72 % (range 96.06 to 100 %).

Direct care staff also recorded the frequency of each problem behavior during half-hour intervals throughout the day. Most direct care staff used clickers to tally each behavior and then recorded the frequency at the end of each half-hour interval on a standardized data sheet. Operational definitions

Table 2 Sleep data for individual participants included in the analysis

No.	Nights in study	Hours of sleep needed	% Low sleep	Mean hours of sleep	
				Low sleep	Average sleep
001	38	8.5	28.95	5.18	7.56
002	52	10	50.00	7.10	8.85
003	96	8.5	19.79	4.46	8.01
004	32	10	21.88	7.00	9.54
005	111	10	40.54	6.77	8.69
006	255	11	35.69	7.83	9.71
007	172	10	55.81	6.64	8.45
008	82	8.5	24.39	4.50	8.05
009	162	8.5	23.46	4.03	8.68
010	123	10	42.28	6.38	9.15
011	60	8.5	26.67	4.84	7.42
012	89	10	28.09	6.60	8.90
013	178	7	24.16	2.38	7.15
014	87	10	29.89	6.50	8.99
015	24	8.5	41.67	5.35	7.57
016	160	10	42.50	6.77	8.67
017	390	10	23.33	6.64	9.09
018	167	10	25.15	6.82	8.88
019	123	11	23.58	7.95	9.78
020	54	10	55.56	6.12	9.04
021	36	8.5	30.56	5.05	8.62
022	300	10	24.33	7.22	8.64

were designed for each participant's problem behavior, and these were included in a binder carried with the participant at all times to increase consistency in data collection across staff.

Procedures

We reviewed each participant's sleep data to identify nights with low sleep, operationally defined as two or more hours less sleep a night than the minimum sleep requirement based on age recommendations from the National Sleep Foundation (n.d.). If the individual was over the half-year mark until his or her next birthday for the majority of the data collection period, the older age classification was used. All other nights were considered average sleep. The experimenter determined the percentage of nights in which the participant had low sleep, and participants were included if they had sleep variability, defined as at least 20 % of nights with low sleep (rounded to the nearest whole percent). Data from at least three nights of low sleep and average sleep were required for the participant to be included in the analysis. If less than three nights were present in either category (e.g., if the participant only had average sleep on two nights), the sample was considered insufficient.

Because the participants were admitted to the inpatient unit with the goal of developing a treatment plan aimed at reducing their problem behavior, only data collected prior to the implementation of an individual's behavioral treatment was included in the analysis. During this phase of the inpatient admission, the direct care staff provided attention, escape, and toys contingent on any instance of problem behavior. For example, during nonessential demands (e.g., academics), staff allowed at least 30 s of escape following any instance of problem behavior. If problem behavior occurred in the presence of a preferred item, the item was delivered to the patient when possible. Finally, a brief statement of concern was provided contingent on problem behavior across all settings. Essential demand times (e.g., toileting, eating, medical appointments, bathing) and times when the behavior team was conducting evaluations were not included in the daily rates of problem behavior. If problem behavior data or sleep data were missing from a participant's file, we excluded that day and the previous night from analyses.

Functional Analysis FAs were conducted for each participant upon admission to the inpatient unit. Initial functional analyses for most individuals followed standard guidelines outlined by Iwata et al. (1984/1994), with idiosyncratic modifications

(e.g., adding a divided attention condition) tailored to each participant based on parental report and preliminary observations. Each FA graph was evaluated using visual analysis methods outlined by Roane et al. (2013). Under these procedures, upper criterion (one standard deviation above the mean) and lower criterion (one standard deviation below the mean) lines are drawn around the control condition (e.g., toy play). Each test condition is then evaluated using the number of data points that fall above the upper criterion and below the lower criterion. In addition, specific rules are applied to account for upward trends, downward trends, low rates of problem behavior, low magnitude effects, multiply maintained problem behavior, and problem behavior maintained by automatic reinforcement (see Appendix in Roane et al. 2013 for a complete list of criteria).

Full-Day Analysis For the first analysis, the experimenter compared each participant's average hourly rate of problem behavior the day after low sleep to the day after an average night's sleep. The difference between rates following days with low and average sleep was compared to the standard deviation in the rate following average sleep. A correlation coefficient (Pearson's r) was also calculated for each participant to determine the relationship between the amount of sleep and problem behavior observed the next day. Finally, the mean rate of problem behavior for days following low sleep and average sleep for all participants was compared using a within-group t test.

In addition, the experimenter conducted a visual analysis of daily rate of problem behavior to determine if the graphed data suggested a difference in problem behavior between days following low and average sleep (see Fig. 1). Three independent observers blind to the purpose of the study also conducted a visual analysis of each graph (with the low sleep and average

Fig. 1 Full-day analysis graph for participant 019. Closed circles indicate data collected on days with previous nights of low sleep, and open diamonds indicate data collected on days with prior nights of average sleep

sleep labels removed) and provided a “yes” or “no” response as to whether the two data paths showed differentiated levels of problem behavior. Agreement between the experimenter and each independent observer was conducted by dividing the number of graphs with agreement by the total number of graphs analyzed and multiplying by 100. IOA for the visual analysis from the three blind observers was 91, 100, and 100 %.

Academic Analysis The academic analysis compared problem behavior during academic demand periods on days following low and average sleep. Unfortunately, eight participants were missing academic data from their files or did not receive academic instruction during the pretreatment phase of the admission. Thus, we conducted this analysis for the remaining 14 participants. The procedures were identical to the full-day analysis, except that only problem behavior during academic instruction periods was included. IOA for the visual analysis for each of the three independent observers was 100 %.

Exploratory Analyses In addition to the 1-day analyses described above, data were also summarized using a lag analysis to compare the rate of problem behavior 2 days following a night of low sleep to determine if low sleep had delayed effects on problem behavior. For this lag analysis, the 2 days immediately following a night of low sleep were considered low sleep days, and days following three nights of average sleep were considered average sleep days. The mean rate of problem behavior on low sleep days was compared to the mean rate of problem behavior on average sleep days, using the same criteria described above for the 1-day lag analysis.

To determine whether the selected cutoff of percentage of nights with low sleep affected our results, we conducted another exploratory analysis to evaluate different inclusion criterion with regard to the percentage of nights of low sleep required. Specifically, the data were analyzed using an expanded inclusion criterion of only 15 % of nights with low sleep (as opposed to 20 % in the original sample). This extended sample was evaluated using the repeated measures t test described above and a comparison of the means of problem behavior after low and average sleep for each participant (described above).

Results

Functional Analysis

The majority of participants underwent multiple FAs, and each was included in the analysis making a total of 47 FAs (mean of 2.14 FAs per participant). Of these, 39 were conducted in a multielement design, and eight were conducted in a

pairwise design. The review of the FA graphs indicated that ten participants engaged in problem behavior maintained by multiple functions and four participants' functional analyses were undifferentiated (i.e., we were unable to determine a clear function). In summary, eight participants engaged in problem behavior maintained by escape from demands, 11 engaged in problem behavior maintained by social attention, 11 engaged in problem behavior maintained by access to preferred items (e.g., toys or food), and four engaged in problem behavior maintained by automatic reinforcement. See Table 1 for FA outcomes by individual participant.

Full-Day Analysis

In the full-day analysis, all participants exhibited similar rates of problem behavior when comparing days after low sleep to days after average sleep once variability had been accounted for. In other words, for all participants, the difference between the rate of problem behavior after low compared to average sleep was less than one standard deviation of the rate of problem behavior on days following an average night's sleep (see Table 3 and Fig. 2). The mean correlation between sleep and problem behavior for the full-day analysis was small ($r=.03$).

Individual correlations ranged from $-.17$ to $.36$. Only three participants had a correlation over $.20$, and all of these participants demonstrated a positive correlation. In addition, there was no statistically significant difference between rate of problem behavior following average sleep and low sleep for the group as a whole, $t(21)=1.27$, $p=.22$. Further supporting this, the visual analysis determined that all of the participants' graphs in the full-day analysis had undifferentiated results between the data path representing problem behavior on days following low sleep and average sleep.

Academic Analysis

Only one participant (004) demonstrated an increase in the frequency of problem behavior during academics following nights with low sleep (i.e., the difference was greater than the standard deviation of the problem behavior following average sleep) as seen in Fig. 3. The mean correlation for participants' sleep and problem behavior during academics was insignificant ($r=-.02$), with individual participant correlations ranging from $-.53$ to $.33$. Two participants showed negative correlations over $.20$: $r(12)=-.57$ and $r(81)=-.27$ for participants 004 and 006, respectively. Participants 011 and 012 also

Table 3 Mean (SD) rate of problem behavior for participants with sleep variability and correlation coefficient between sleep and problem behavior for each participant, indicated by r

No.	Full day			Academics		
	Low sleep	Average sleep	r	Low sleep	Average sleep	r
001	111.63	99.86 (76.20)	-0.08			
002	16.70	12.51 (10.93)	-0.17	62.53	67.99 (53.86)	-0.01
003	445.29	415.50 (419.65)	-0.05			
004	99.54	93.30 (77.53)	0.15	178.17 ^a	80.69 ^a (86.81)	-0.53
005	67.80	60.26 (35.09)	-0.01	102.12	84.52 (78.35)	-0.16
006	65.75	56.64 (40.56)	-0.17	151.48	97.26 (80.17)	-0.27
007	17.93	14.11 (28.47)	-0.13	0.39	0.45 (1.19)	-0.19
008	3.91	2.20 (3.75)	-0.07			
009	17.12	10.70 (20.08)	-0.12			
010	54.93	34.58 (33.00)	-0.17	41.65	45.03 (42.86)	0.00
011	5.41	5.39 (6.43)	-0.01	10.28	21.33 (26.20)	0.33
012	32.24	35.83 (16.92)	0.24	4.18	8.08 (9.43)	0.30
013	28.57	40.32 (36.67)	0.19	61.49	60.27 (94.83)	-0.06
014	2.65	4.74 (5.79)	0.25			
015	12.53	19.28 (10.96)	0.36			
016	7.96	11.24 (9.64)	0.08			
017	15.40	22.64 (19.36)	0.12	16.70	33.27 (58.87)	0.18
018	13.12	17.29 (12.07)	0.19	70.35	57.61 (35.17)	-0.06
019	5.76	6.73 (5.97)	-0.02			
020	11.45	14.60 (11.76)	0.01	37.71	29.45 (22.51)	-0.03
021	2.24	2.44 (3.45)	-0.01	2.51	4.15 (7.86)	0.15
022	18.93	20.61 (22.45)	0.12	95.26	111.76 (110.46)	0.10

^a Difference is greater than one standard deviation of the problem behavior exhibited after average sleep

Fig. 2 Mean rate of problem behavior for each participant during the full day following low and average sleep. Error bars represent one standard deviation above and below the mean rate of problem behavior exhibited on days following average sleep (due to participant 003's unusually high rates of problem behavior, a secondary y-axis was used for her data (asterisk))

showed moderate correlations but in the positive direction (.33 and .30 respectively). There was no statistically significant differences between low sleep and average sleep for the group, $t(13)=1.15, p=.27$ (see Fig. 3 and Table 3). The visual analysis determined that none of the graphs had differentiated results between the data path representing problem behavior on days following low sleep and average sleep.

The lack of relationship between sleep and problem behavior for the vast majority of our participants suggests that the function of problem behavior did not result in differential effects of low sleep. None of the eight participants with an identified escape function engaged in higher rates of problem

Fig. 3 Mean rate of problem behavior during academics on days following low and average sleep. Error bars represent one standard deviation above and below the mean rate of problem behavior exhibited on days following average sleep

behavior following nights of low sleep and the correlation between sleep and problem behavior (mean $r=.10$) was low.

Exploratory 2-Day Lag Analysis

Results from the lag analysis were in agreement with the 1-day analysis for all but one participant. For participant 010, problem behavior on low-sleep days ($M=49.87$) was more than one standard deviation higher than problem behavior on average sleep days ($M=25.68$).

Including participants with only 15 % of nights with low sleep in the analysis yielded an additional seven participants. This did not lead to discrepant results from the sample identified using the 20 % cutoff. In other words, there was still no significant difference in problem behavior between days following low and average sleep, $t(28)=-1.14, p=.26$.

Discussion

In the current study, there was no significant difference in problem behavior on days following low sleep compared to days following an average night's sleep. With the exception of one case, any differences in the mean rate of problem behavior across the day and in academics could be accounted for by general variability in problem behavior (the difference was not greater than one standard deviation of the sample). This finding was further supported by insignificant correlations for all participants in the full-day analysis and most participants in the academics analysis. It is also interesting to note that three participants in the full-day analysis and two in the academics analysis demonstrated moderate relationships between sleep and problem behavior opposite of the hypothesized relationship (increased problem behavior associated with more sleep). In addition, visual analyses suggested that a data path representing rate of problem behavior following nights with low sleep was not differentiated from a data path representing rate of problem behavior following nights with average sleep. Our findings are contradictory to the majority of previous research in this area, which has suggested that sleep and problem behavior are related (Mazurek et al. 2013; Rzepecka et al. 2011) and that low sleep leads to increased problem behavior (Kennedy and Meyer 1996; O'Reilly 1995).

There are several possible explanations for the incongruence between our results and prior research. First, in studies that found a relationship between sleep and problem behavior using direct observation data collection, there were differences in the types of participants recruited. In previous studies, participants were identified because indirect assessments suggested that sleep might have an effect on problem behavior (e.g., Kennedy and Meyer 1996) limiting the generalizability of the finding to other populations. The population used in this

analysis was taken from an archival database, and although participants were screened for sleep variability, they were selected without reference to prior hypotheses that low sleep resulted in higher rates of problem behavior. Therefore, while there is a relationship between sleep and problem behavior in a select group of individuals, it may not hold true for other individuals.

Another important distinction from previous research is that the individuals in our study engaged in problem behavior maintained by a variety of functions. Previous research using direct observation methods focused on specific behavioral functions, primarily escape-maintained problem behavior, to evaluate the effects of limited sleep (e.g., O'Reilly 1995). We specifically evaluated this in our sample by examining the records of those participants who exhibited problem behavior maintained by escape from demands and found that there was no relationship between problem behaviors and sleep when comparing data collected across the day. To control for the context, we also evaluated frequency of problem behavior during academic periods of the day and still found no consistent relationship with sleep and problem behavior. In addition, the two participants who did have a higher frequency of problem behavior during academics following nights of low sleep had problem behavior maintained by automatic reinforcement.

Our sample was broader and more representative of individuals with severe problem behavior than previous reports with this population, in that we did not screen specifically for participants with a hypothesized relationship between sleep and problem behavior or for a specific function of problem behavior. However, our sample was still limited in that all participants were admitted to an inpatient treatment program, and this was a retrospective rather than prospective analysis. These results may not be generalizable to individuals in other home settings where sleep schedules can vary significantly, sleep routines may be less structured, and treatment services may be less intensive. The participants were also fairly heterogeneous, and the majority of participants were diagnosed with multiple psychiatric and medical disorders accompanied with an intellectual disability. This may limit the generalizability of our results to typically developing individuals or those with developmental delays without multiple diagnoses. In addition, it is not clear how these results relate to individuals with less severe problem behavior (e.g., low intensity disruptive behaviors, off-task behavior, noncompliance).

Another possible explanation for the discrepancy between this study and prior research is our data collection method (i.e., direct observation of both problem behavior and sleep) differed from caregiver-report methods used in the majority of previous studies (e.g., Anders et al. 2012). Because we did not recruit caregiver report of problem behavior or sleep problems, it is not clear how this methodological difference would have affected our results. Future research could better evaluate

this difference by comparing parental or staff report to direct observation.

It is possible that a night of low sleep might have a more complex relationship with rates of problem behavior than was evaluated in this study. For example, there may be a delayed effect of lack of sleep on problem behavior. To assess for this, exploratory lag analyses were conducted looking at rate of problem behavior 2 days following a night of low sleep. This analysis had similar results to the full-day analysis in that there was no consistent pattern observed between sleep and problem behavior. Future research would benefit from further investigation of other data analysis models, such as how more than one consecutive night with low sleep affects behavior.

Another interesting area for future investigation is the relationship between problem behavior and other aspects of sleep, such as quality of sleep and time spent in specific sleep stages. The current study utilized direct observation by trained staff to measure sleep, and these observations do not provide sufficient information to analyze more complex aspects of sleep. Using methods such as polysomnography, actigraphy, and motion detection video would add to our knowledge about quality of sleep in addition to getting awake/asleep data. These methods are not always feasible in the clinical setting due to their high cost and difficulties in implementation with people with noncompliance and other problem behavior (Bourne et al. 2007). Future research might work to remedy this problem by identifying direct observation methods that are reliable with other measurement systems.

A potential limitation of this study is the focus exclusively on nighttime sleep. Daytime sleep, such as naps, was not included in the sleep calculations but may have affected the child's drowsiness and impacted the relationship between sleep and problem behavior. In addition, although a national developmental norm was used to determine the amount of sleep the participant should receive, classifying a night of low sleep as 2 h less than the norm is not empirically supported. However, the low correlation between the nightly hours of sleep and the rate of problem behavior the following day suggests that this cutoff may be valid. Similarly, our inclusion criteria of participants with at least 20 % of nights with low sleep was selected somewhat arbitrarily based on the percentage of nights that the experimenters agreed would indicate variability. However, the exploratory analysis suggested that a less stringent criterion (i.e., 15 % of nights with low sleep) did not change the results, supporting that the 20 % criteria was not too stringent. There were also no notable differences in the results for individuals at one end of the continuum with a larger percentage of nights with sleep variability (e.g., 55.81 and 50.00 % for participants 007 and 002) than those on the lower end of the continuum, suggesting that a more stringent inclusion criterion would not have changed the results of the study. Nonetheless, future research could benefit from comparing rates of problem behavior following low sleep and

average sleep with a variety of cutoff points to determine if there is an optimal level that affects problem behavior.

In addition to refining the measure of sleep, future research could also benefit from measuring additional environmental variables that might impact sleep. It may be the case that low sleep occurs for a variety of reasons, and these reasons may also have an impact on problem behavior. For example, it might be that low sleep is predictive of problem behavior, but only in specific cases. The current study used retrospective analysis of records, and because of this, we were unable to isolate variables that may have contributed to sleep and problem behavior (e.g., illness, pain, menstruation, etc.) which have been suggested as motivating operations for problem behavior (Carr and Smith 1995; Iwata et al. 2000). We were also unable to analyze the effects of medication changes on sleep and problem behavior. Future research could look at a wider range of variables that might affect both sleep and problem behavior, including medication and physiological variables, to assist in more clearly defining the relationship between sleep and problem behavior.

The results of this study have direct implications on clinical practice. Clinicians are often faced with parental report suggesting that sleep might be affecting problem behavior, and this report might be difficult to interpret when it is unclear from data-collected whether there is a direct relationship. If a clinician in this situation assumes a relationship between problem behavior and sleep exists when in fact it does not, he/she may misinterpret the results of an assessment or treatment evaluations. In addition, it is possible that by misattributing increased rates of problem behavior to low sleep, a clinician may overlook other important antecedent variables related to problem behavior on those days. Considering this, an important implication of this study for clinicians is that the relationship between sleep and problem behavior should be directly evaluated before making any treatment decisions or altering the interpretation of behavioral data based on the impact of sleep. To further assist with clinical care, future research might develop a brief screening measure that could identify individuals at risk for having physiological factors that serve as motivating operations for problem behavior. Results of a brief assessment could then be used to determine whether a more comprehensive evaluation, such as the one conducted in this study, is warranted.

Conflict of Interest The authors declare that they have no conflict of interest.

References

- Anders, T., Iosif, A., Schwichtenberg, A. J., Tang, K., & Goodlin-Jones, B. (2012). Sleep and daytime functioning: a short-term longitudinal study of three preschool-age comparison groups. *American Journal on Intellectual and Developmental Disabilities, 117*, 275–290. doi:10.1352/1944-7558-117.4.275.
- Brylewski, J., & Wiggs, L. (1999). Sleep problems and daytime challenging behavior in a community-based sample of adults with intellectual disabilities. *Journal of Intellectual Disability Research, 43*, 504–512. doi:10.1046/j.1365-2788.1999.00234.x.
- Bourne, R. S., Minelli, C., Hills, G. H., & Kandler, R. (2007). Clinical review: sleep measurement in critical care patients: research and clinical implications. *Critical Care, 11*, 1–17. doi:10.1186/cc5966.
- Carr, E. G., & Smith, C. E. (1995). Biological setting events for self-injury. *Mental Retardation and Developmental Disabilities Research Reviews, 1*, 94–98. doi:10.1002/mrdd.1410010204.
- DeLeon, I. G., Fisher, W. W., & Marhefka, J. M. (2004). Decreasing self-injurious behavior associated with awakening in a child with autism and developmental delays. *Behavioral Interventions, 19*, 111–119. doi:10.1002/bin.154.
- Dominick, K. C., Davis, N. O., Lainhart, J., Tager-Flusberg, H., & Folstein, S. (2007). A typical behaviors in children with autism and children with a history of language impairment. *Research in Developmental Disabilities, 28*, 145–162. doi:10.1016/j.ridd.2006.02.003.
- Emerson, E., Kiernan, C., Alborz, A., Reeves, D., Mason, H., Swarbrick, R., & Hatton, C. (2001). The prevalence of challenging behaviors: a total population study. *Research in Developmental Disabilities, 22*, 77–79. doi:10.1016/S0891-4222(00)00061-5.
- Eshbaugh, B., Martin, W., Cunningham, K., & Luiselli, J. K. (2004). Evaluation of a bedtime medication regimen on daytime sleep and challenging behaviors of an adult with intellectual disabilities. *Mental Health Aspects of Developmental Disabilities, 7*, 21–25. Retrieved from http://media.wix.com/ugd/e11630_bc84176c8201bc5a2b8a310c0ad3f980.pdf.
- Ferber, R. (1985). *Solve your child's sleep problems*. New York, NY: Simon & Schuster.
- Horner, R. H., Day, H. M., & Day, J. R. (1997). Using neutralizing routines to reduce problem behaviors. *Journal of Applied Behavior Analysis, 30*, 601–614. doi:10.1901/jaba.1997.30-601.
- Iwata, B. A., Dorsey, M. F., Slifer, K. J., Bauman, K. E., & Richman, G. S. (1982). Toward a functional analysis of self-injury. *Analysis and Intervention in Developmental Disabilities, 2*, 3–20. doi:10.1016/0270-4684(82)90003-9.
- Iwata, B. A., Dorsey, M. F., Slifer, K. J., Bauman, K. E., & Richman, G. S. (1994). Toward a functional analysis of self-injury. *Journal of Applied Behavior Analysis, 27*, 197–209. doi:10.1901/jaba.1994.27-197.
- Iwata, B. A., Smith, R. G., & Michael, J. (2000). Current research on the influence of establishing operations on behavior in applied settings. *Journal of Applied Behavior Analysis, 33*, 411–418. doi:10.1901/jaba.2000.33-411.
- Kennedy, C. H., & Meyer, K. A. (1996). Sleep deprivation, allergy symptoms, and negatively reinforced problem behavior. *Journal of Applied Behavior Analysis, 29*, 133–135. doi:10.1901/jaba.1996.29-133.
- Langhorne, P., McGill, P., & Oliver, C. (2013). The motivation operation and negatively reinforced problem behavior: a systematic review. *Behavior Modification, 38*, 107–159. doi:10.1177/0145445513509649.
- Laraway, S., Snyderski, S., Michael, J., & Poling, A. (2003). Motivation operations and terms to describe them: some further refinements. *Journal of Applied Behavior Analysis, 36*, 407–414. doi:10.1901/jaba.2003.36-407.
- Mazurek, M. O., Kanne, S. M., & Wodka, E. L. (2013). Physical aggression in children and adolescents with autism spectrum disorders. *Research in Autism Spectrum Disorders, 7*, 455–465. doi:10.1016/j.rasd.2012.11.004.

- Michael, J. (1982). Distinguishing between discriminative and motivational functions of stimuli. *Journal of the Experimental Analysis of Behavior*, 37, 149–155. doi:10.1901/jeab.1982.37-149.
- Murphy, O., Healy, O., & Leader, G. (2009). Risk factors for challenging behaviors among 157 children with autism spectrum disorder in Ireland. *Research in Autism Spectrum Disorders*, 3, 474–482. doi:10.1016/j.rasd.2008.09.008.
- National Sleep Foundation (n.d.). *How much sleep do we really need*. Retrieved from <http://sleepfoundation.org/how-sleep-works/how-much-sleep-do-we-really-need> Accessed November 2013.
- O'Reilly, M. (1995). Functional analysis and treatment of escape-maintained aggression correlated with sleep deprivation. *Journal of Applied Behavior Analysis*, 28, 225–226. doi:10.1901/jaba.1995.28-225.
- O'Reilly, M. F., & Lancioni, G. (2000). Response covariation of escape-maintained aberrant behavior correlated with sleep deprivation. *Research in Developmental Disabilities*, 21, 125–136. doi:10.1016/S0891-4222(00)00029-9.
- Piazza, C. C., Fisher, W. W., & Kahng, S. W. (1996). Sleep patterns in children and young adults with mental retardation and severe behavior disorders. *Developmental Medicine and Child Neurology*, 4, 335–344. doi:10.1111/j.1469-8749.1996.tb12099.x.
- Roane, H. S., Fisher, W. W., Kelley, M. E., Mevers, J. L., & Boussein, K. J. (2013). Using modified visual-inspection criteria to interpret functional analysis outcomes. *Journal of Applied Behavior Analysis*, 46, 130–146. doi:10.1002/jaba.13.
- Rzepecka, H., McKenzie, K., McClure, I., & Murphy, S. (2011). Sleep, anxiety and challenging behavior in children with intellectual disability and/or autism spectrum disorder. *Research in Developmental Disabilities*, 32, 2758–2766. doi:10.1016/j.ridd.2011.05.034.
- Sovner, R., Fox, C. J., Lowry, M. J., & Lowry, M. A. (1999). Fluoxetine treatment of depression and associated self-injury in two adults with mental retardation. *Journal of Intellectual Disability Research*, 37, 301–311. doi:10.1111/j.1365-2788.1993.tb01287.x.
- Wachtel, L. E. & Hagopian, L. P. (2006). Psychopharmacology and applied behavioral analysis: tandem treatment of severe problem behavior in intellectual disability and a case series. *Israel Journal of Psychiatry and Related Sciences*, 43, 265–274. Retrieved from http://neurology.doctorsonly.co.il/wp-content/uploads/2011/12/2006_4_6.pdf.