Sour Sleep, Sweet Revenge? Aggressive Pleasure as a Potential Mechanism Underlying Poor Sleep Quality's Link to Aggression

in press at *Emotion*

David S. Chester* & Joseph M. Dzierzewski

Department of Psychology

Virginia Commonwealth University, USA

Main Text Word Count (minus References): 7,380

Abstract Word Count: 171

*Correspondence should be addressed to:

David S. Chester

302 Thurston House

808 West Franklin St.

Virginia Commonwealth University

Richmond, VA, 23284, USA

dschester@vcu.edu

Abstract

Sleep quality is a critical component of successful human functioning. Poor sleep quality is associated with aggressive behavior, yet the psychological mechanisms that drive this effect are incompletely understood. We tested the prediction that the association between poor sleep quality and aggression would be explained, in part, by a magnified experience of positive affect during aggression. We conducted two cross-sectional studies (Study 1 *N* = 388; Study 2: *N* = 317) and a third preregistered study (*N* = 379), which tested for mediation across two waves that were separated by 14-42 days. Across all three studies, we replicated the positive association between poor sleep quality and aggression. However, we did not observe compelling or consistent evidence that poor sleep quality is linked to greater positive affect during aggression. Such aggressive pleasure was temporally-stable and predicted subsequent increases in aggressive behavior. These findings support a reinforcement model of aggressive affect, in which the pleasure of aggression promotes greater aggression over time – perhaps explaining why some individuals are more dispositionally-aggressive than others.

Keywords**:** aggression; sleep quality; social rejection; pleasure; affect

Introduction

Sleep is a universal human behavior. High-quality sleep is vital to both optimal psychological and physiological functioning (Pilcher, Ginter, & Sadowsky, 1997). However, the role of sleep quality in *interpersonal* processes has been severely neglected (Gordon, Mendes, & Prather, 2017). Further, the proximate psychological mechanisms that link poor sleep quality to social behaviors are also poorly understood. To fill these gaps in the literature, we examined sleep quality's link to aggressive responses via social rejection and the affective mechanisms that convey these effects.

Sleep Quality: Definition and Links to Human Functioning

Defining sleep quality. While sleep is defined through a combination of changes in brain waves, posture, and consciousness (Carskadon, & Dement, 2011), sleep *quality* generally lacks a widespread accepted operational definition (Krystal & Edinger, 2008). The quantity and quality of one's sleep can be assessed through multiple different means, grouped into objective methods (e.g., polysomnography and actigraphy) and subjective measures (e.g., retrospective questionnaires and prospective diaries). The most commonly used, and most widely accepted, methods to measure sleep quality are subjective in nature (Krystal & Edinger, 2008). Subjective estimates of sleep quality have been shown to represent the global experience of nightly sleep, likely containing information pertaining to context, sleep quantity, and personal characteristics of the rater (Krystal & Edinger, 2008).

Sleep and social functioning. Measures of sleep quality are reliably related to numerous important variables, such as general health (Pilcher et al., 1997), cognitive health (Dzierzewski, Dautovich, & Ravyts, 2018), and mental health (Kay &

Dzierzewski, 2015; Ramsawh, Stein, Belik, Jacobi, & Sareen, 2009). Building on these literatures, several studies have investigated the role of sleep quality in *social* processes, implicating it as a critical determinant of healthy interpersonal functioning. Good sleep quality was linked to greater frequency and stability of active social interactions among undergraduates (Carney, Edinger, Meyer, Lindman, & Istre, 2006). Poor sleep quality is also associated with poorer relationship quality (i.e., less satisfaction, higher rate of divorce, less intimacy, more conflict) among married couples (for a review see Troxel, Robles, Hall, & Buysse, 2007). Even among unmarried romantic dyads, one or both partners' poor sleep quality was associated with greater relationship conflict (Gordon & Chen, 2014). Good sleep quality seems to be a prerequisite for interpersonal harmony, while poor sleep quality may promote the infliction of harm on others.

Poor Sleep Quality and Aggression

Aggression is defined as any attempt to harm someone against their will and is caused by a host of factors (Anderson & Bushman, 2002). A number of studies have emerged to suggest that poor sleep quality is a robust correlate of greater aggressive behavior, and likely plays a causal role in motivating human violence (for reviews see Kamphuis, Meerlo, Koolhaas, & Lancel, 2012; Krizan & Herlache, 2016). However, several studies have failed to replicate the link between sleep quality and greater aggression (e.g., Lindberg et al., 2003; Shin et al., 2005). Although the literature is somewhat mixed, the bulk of the evidence supports the link between sleep quality and aggression and spans the developmental trajectory from childhood to adolescence to adulthood.

Evidence from children and adolescents. A considerable portion of the empirical evidence for the link between poor sleep and aggression has been obtained by researchers focusing on children and adolescents. Beginning at 2 and 3 years of age, sleep problems accounted for a significant portion of the variance in problematic externalizing behaviors (Reid, Hong, & Wade, 2009). Across male and female adolescents, poor sleep quality was associated with greater self-reported aggressive behavior (Meijer, Reitz, Deković, Van Den Wittenboer, & Stoel, 2010). Among adolescent and emerging adult offenders, poor sleep quantity and quality were correlated with greater self-reported aggressive traits (Ireland & Culpin, 2006). Among adolescents, poor sleep quality was linked to impaired control over their aggressive impulses, suggesting that poor sleep quality may promote aggression via affective dysregulation (Meijer, Habekothe, & Van Den Wittenboer, 2000).

Evidence from adults. Research on sleep quality and aggression in adults has spanned forensic and clinical populations and healthy volunteer samples. Psychiatric in-patients with poor self-report sleep quality reported more aggressive traits and were rated as more aggressive by clinicians and were more likely to have been in aggressive altercations with other patients (Kamphuis, Dijk, Spreen, & Lancel, 2014). Soldiers with antisocial personality disorder also exhibited correlations between their sleep quality and aggressive traits (Semız et al., 2008). Among a healthy sample, 55 hours of sleep deprivation increased hostile attributions and behaviors and experiences of interpersonal frustration (Kahn-Greene, Lipizzi, Conrad, Kamimori, & Killgore, 2006). Dissatisfaction with sleep was associated with a higher likelihood of having been in a physical fight among a nationally-representative sample of African-American

participants (Vaughn, Salas-Wright, White, & Kremer, 2015). Among police offers, those with disordered sleep breathing were more aggressive towards suspects (Rajaratnam et al., 2011). These preliminary investigations indicate that even among adults, poor sleep quality is a robust predictor of aggressiveness. Yet why would poor sleep quality promote such hostile behavior?

Dysregulated Affect: A Potential Mechanism.

Sleep helps us navigate our world by constraining our affective impulses. Supporting this statement, poor sleep quality is reliably linked to poor affect-regulation (Thomsen, Mehlsen, Christensen, & Zachariae, 2003). Given the reliable role of negative and positive affect in promoting aggressive behavior (Berkowitz, 1982; Chester, 2017), dysregulated and exacerbated affective responses may serve as a mechanism through which poor sleep quality increases aggression.

Negative affect. Poor subjective sleep quality is correlated with self-reports of impaired ability to control and regulate one's negative affect (Thomsen et al., 2003) and with greater general negative affect (McCrae et al., 2008, 2014). Undergraduates report greater angry rumination when they have recently had poor sleep quality (Stoia-Caraballo et al., 2008) and sleep quality and trait anger were strongly, positively correlated in a large sample of adults (Shin et al., 2005). On laboratory affect-regulation tasks, individuals who report worse subjective sleep quality are less able to adaptively regulate their negative affect (Mauss, Troy, & LeBourgeois, 2013). Those who experience poor sleep quality exhibit impaired processing of negatively-valenced information (Soffer-Dudek, Sadeh, Dahl, & Rosenblat-Stein, 2011). Poor sleep quality does not simply affect how we regulate our negative affect, but increases affective

reactivity to provocative stimuli (Gruber & Cassoff, 2014). Indeed, being rejected by one's romantic partner was only associated with subsequent distress if participants reported poor sleep quality on the night before (Gilbert, Pond, Haak, DeWall, & Keller, 2015). Dysregulated and exacerbated negative affective responses to interpersonal provocations thus appears to be a likely consequence of poor sleep quality.

Positive affect. Most of the research on sleep and affect has focused on negatively-valenced affective states. Among the subset of studies that examine positively-valenced affect, there is heterogeneous, yet mostly consistent, evidence that sleep quality is linked to stable levels of higher positive affect (Ong, Kim, Young, & Steptoe, 2017). Indeed, positive affect in response to daily life events was associated with both greater and lesser sleep quality on the previous night (Sin et al., 2017). A reason for this heterogeneity might be that sleep quality shares different associations with various forms of positive affect (Pressman, Jenkins, Kraft-Feil, Rasmussen, & Scheier, 2017). More specifically, sleep quality is linked to forms of positive affect that are associated with greater arousal (e.g., vigor) and to transient feelings of low-arousal positive affect (e.g., calm; Pressman et al., 2017). These forms of correlational evidence are bolstered by sleep deprivation studies. A sleep deprivation experiment elicited greater reactivity in the brain's reward circuitry in response to pleasant stimuli and reduced functional connectivity between these reward regions and their regulatory counterparts in the prefrontal cortex (Gujar, Yoo, Hu, & Walker, 2011). Sleep deprivation also increased participants' neural and subjective responses to appetitive food (Benedict et al., 2012). As such, the ability of sleep quality to elicit exaggerated positive affect appears to be driven both by increases in bottom-up reward reactivity and

deficits in top-down inhibitory control. These findings suggest that sleep quality dysregulates both negative and positive affect. Such unrestrained positive affect has remarkable implications for aggressive behavior.

The Role of Positive Affect in Aggression

Aggression is most often construed as a 'hot', affect-driven behavior, with 'cold and calculating' forms of violence being relatively rare (Anderson & Bushman, 2002). The reigning champion of reliable, proximate causes of aggression is negatively-valenced affective states such as pain, anger, and frustration (Berkowitz, 1982). However, a focus on negatively-valenced states ignores the growing literature that supports the role of positive affect in aggression . A host of studies have supported the existence of *aggressive pleasure* (for a review see Chester, 2017). Aggressive pleasure is construed as a feeling state that exists within the theoretical space of core affect as a blend of positively-valenced hedonic pleasure and activated levels of arousal (Barrett & Bliss-Moreau, 2009; Russell, 2003). This state is akin to 'positive arousal', which arises from striatally-mediated anticipation of rewards (Knutson & Greer, 2008). Further, aggressive pleasure is theorized to entail an approach motivation towards the target of the aggression (Harmon-Jones & Sigelman, 2001). Though aggressive pleasure is examined as a state variable that fluctuates according to the given context, it likely exhibits stable, trait-like individual differences across individuals (Chester, DeWall, & Enjaian, in press). However, the temporal durability of aggressive pleasure remains unexamined.

These conceptualizations are supported by findings that retaliatory forms of aggression are described in positively-valenced terms (Eadeh, Peak, & Lambert, 2017),

improve individuals' self-reported mood (Chester & DeWall, 2017), and are linked to greater activity in the brain's dopaminergic reward circuitry (Chester & DeWall, 2016). Unprovoked aggression can also be rewarding, with individuals reporting sadistic pleasure being associated with aggressive acts directed towards innocent victims (Buckels, Jones, & Paulhus, 2013; Chester et al., in press). As such, the present research examines both retaliatory and non-retaliatory forms of aggression.

Overview

Poor sleep quality is associated with increased aggressive behavior, yet the mechanisms that explain this link remain poorly understood. We conducted a series of studies with diverse samples to test the hypothesis that participants who reported poorer sleep quality would exhibit greater aggressive behavior, which would be partially explained by greater positive affect experienced during the aggressive act. We further predicted that this indirect effect would be magnified among rejected participants who were retaliating in response to this social slight, and not among the unprovoked participants in the acceptance condition.

Open Practices and Ethics Statement

De-identified data necessary to reproduce all analyses from this project have been made publicly available at https://osf.io/qnha2/files/. All research procedures were approved by the appropriate research ethics committee.

Study 1[1]

[1] Analyses on aggression and affect data from this study also appear in Chester and colleagues (in press). Some descriptive statistics are reproduced, but this data has not been reported on in any published work in regards to its relation with sleep quality.

Materials and Methods

Participants

Participants were 388 undergraduates enrolled in an introductory psychology course: 249 females, 134 males, 2 other, 3 missing gender data; age *M* = 19.58, *SD* = 2.39, range 18-44. Participants also reported their ethnic-racial identities: 44 Hispanic, 344 non-Hispanic; 12 Arabic, 65 Asian, 95 Black, 1 Native-American, 170 White, 51 Other. Given the preliminary nature of this investigation, the anticipated size of our predicted indirect effects were not known. Therefore, we sought to obtain the largest sample we could within a single academic semester from the given psychology subject pool. Our sample size is justified as previous research has suggested that 300 participants are sufficient to power a modest moderated mediation effect at 80% power (Preacher, Rucker, & Hayes, 2007). Participants received research credit towards their class's research requirement for their participation.

Materials

Need Threat Scale. The 28-item Need Threat Scale assesses the aversive experience of social rejection (hereafter 'social distress') by assessing the extent to which the Cyberball task impacted feelings of rejection, belonging, control, meaningful existence, and self-esteem, as well as negative and positive affect (Williams, 2009). This measure served as a manipulation check for the Cyberball task. Each item instructed participants to retrospectively report their subjective experience *during* the Cyberball game (sample items: 'I was ignored', 'I felt rejected'). The social distress index was calculated by averaging across all corresponding items, while reverse-scoring the positive affect subscale.

Pittsburgh Sleep Quality Index. The Pittsburgh Sleep Quality Index (PSQI; Buysse, Reynolds, Monk, Berman, & Kupfer, 1989) was used to assess self-reported sleep quality. The PSQI is a well validated measure of sleep quality, which has been used with a variety of samples (i.e., children through older adults; Dzierzewski et al., 2015; Ikeda, Nagai, Kato-Nishimura, Mohri, & Taniike, 2012) and investigations spanning the continuum of health and sleep (Buysse et al., 1989; Dzierzewski et al., 2015). The 19-items of the PSQI are combined to create 7 unique component scores (sleep duration, sleep latency, dysfunction due to sleepiness, sleep efficiency, needing medication to sleep, subjective sleep quality, and sleep disturbance), which are averaged to calculate a PSQI total score (possible range: 0 – 21). The PSQI total score is commonly used to measure poor sleep quality, with higher score being indicative of worse overall sleep quality (Buysse et al., 1989).

Positive Affect During Aggression Scale. In order to quantify the pleasure of aggression, we employed the Positive Affect During Aggression Scale (PADAS; Chester et al., in press). Participants retrospectively reported whether they experienced 9 positively-valenced affective states (e.g., pleasant) during their pin placement in the Voodoo Doll Aggression Task using a 1 (strongly disagree) to 7 (strongly agree) response scale. Items were averaged to create an aggressive pleasure index for each participant.

Voodoo Doll Aggression Task. The Voodoo Doll Aggression Task (VDAT) was administered in the form of a computer task that instructed participants to view an inanimate doll as representative of an actual human being (e.g., romantic relationship partners; DeWall et al., 2013). Then, participants could virtually stab 0 to 51 pins in the

doll by dragging a slidebar across the computer screen. The number of pins they selected served as our dependent measure of aggression. This task exhibits substantial convergent validity with other aggression measures, test-retest reliability, and construct validity (Chester & Lasko, in press; DeWall et al., 2013). Scores were computed by adding 1 to all raw scores and then applying a base 10 logarithmic transformation to this data, as doing so reduces issues with skewness and kurtosis (Chester & Lasko, in press).

Procedure

Participants accessed the study on their personal computers by clicking an internet link to an online survey that was ostensibly to examine participants' ability to imagine fictitious events. After providing informed consent, participants were randomly assigned to be either socially rejected or accepted via the Cyberball paradigm (version 4.0; Williams, Cheung, & Choi, 2000; Williams, Yeager, Cheung, & Choi, 2012). In this paradigm, participants were instructed to complete an online test of their mental visualization abilities with two other students from their university. Participants viewed a loading screen that was presumably connecting them with their two partners, who were portrayed as cartoon avatars. Participants randomly-assigned to the acceptance condition received a ball toss approximately one-third of the time, whereas participants randomly-assigned to the rejection condition only received the ball several times in the beginning of the task and then received no tosses as their partners tossed the ball back-and-forth for the rest of the task.

After the Cyberball task, participants reported their feelings of social distress via the Need Threat Scale and then completed the Voodoo Doll Aggression Task, with one

of their Cyberball partners as the target. Finally, participants completed a battery of questionnaires that included the Positive Affect During Aggression Scale and the PSQI. In this study, the PSQI asked participants about their sleep quality over the past month. Embedded in the battery of questionnaires were two attention check items, which instructed participants to select a specific number from a number array.

Results

Descriptive Statistics

Thirty two participants failed the attention check and were screened out of all remaining analyses, final *N* = 356. Descriptive statistics are summarized in Table 1.

Table 1. Descriptive statistics for all variables in Study 1. Means (M) and standard deviations (SD) are presented for each Cyberball condition and for the combined, overall sample. NTS = Need Threat Scale, PADAS = Positive Affect During Aggression Scale, PSQI = Pittsburgh Sleep Quality Index, VDAT = Voodoo Doll Aggression Task.

Measure	Accepted *N* = 179		Rejected *N* = 177		Overall		Range	*α*	Missing
	M	*SD*	*M*	*SD*	*M*	*SD*			
NTS	2.47	0.57	3.54	0.65	3.00	0.81	1 - 4.71	.93	0
PADAS	2.29	1.57	2.54	1.57	2.42	1.58	1 - 7	.95	0
PSQI	6.70	3.39	6.35	3.43	6.52	3.41	0 - 19	.87	42
VDAT	0.44	0.58	0.59	0.62	0.52	0.61	0 - 1,72	n/a	0

Group Comparisons

Validating our rejection manipulation, rejected participants (coded as 1) reported greater social distress, $t(354) = 16.58$, $p < .001$, $d = 1.76$, 95% $CI = 1.51, 1.99$,

compared to accepted participants (coded as -1). Rejected participants also stuck more pins in the voodoo doll that represented one of their Cyberball partners, $t(354) = 2.39$, $p = .017$, $d = 0.25$, 95% $CI = 0.04, 0.46$.

Correlations

Zero-order correlations between all study variables are summarized in Table 2. Against expectations, poor sleep quality was unassociated with aggression or aggressive pleasure.

*Table 2. Zero-order correlations between variables from Study 1. Gender coded as male = 1, female = -1. NTS = Need Threat Scale, PADAS = Positive Affect During Aggression Scale, PSQI = Pittsburgh Sleep Quality Index, VDAT = Voodoo Doll Aggression Task. *p < .05, **p < .01, ***p < .001.*

	Gender	NTS	PADAS	PSQI
NTS	.00			
PADAS	.18**	-.01		
PSQI	-.19**	.13*	.02	
VDAT	.12*	.27***	.03	.08

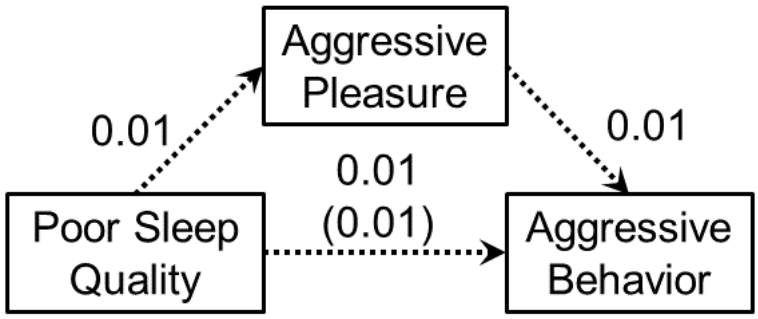
The association between poor sleep quality and aggression was not moderated by Cyberball condition, $B = 0.00$, 95% $CI = -0.02, 0.02$, $SE = 0.01$, $t(310) = -0.12$, $p = .901$. The association between poor sleep quality and aggressive pleasure was not moderated by Cyberball condition, $B = 0.02$, 95% $CI = -0.03, 0.07$, $SE = 0.03$, $t(310) = 0.75$, $p = .452$.

Mediation Modeling

Participants with any missing data were excluded from subsequent moderated mediation modeling, resulting in a final sample of *N* = 314. We constructed a model using PROCESS v.3.1 for SPSS (Hayes, 2012), in which the total PSQI score was modeled as the independent variable, the log-transformed voodoo doll pin count was modeled as the dependent variable, and PADAS scores were modeled as the mediator (PROCESS model 4). The independent and mediator variables were mean-centered.

Using nonparametric, accelerated, and bias-corrected bootstrapping (5,000 re-samples), this overall model did not explain a significant amount of variance in aggression, R^2 = .01, $F(2, 311) = 1.06$, p = .347. No evidence of an indirect effect of greater aggressive pleasure was observed, B = 0.00, SE = 0.00, 95% CI = -0.01, 0.01 (Figure 1). This null indirect effect was not moderated by Cyberball condition, B = 0.00, SE = 0.00, 95% CI = 0.00, 0.00 (PROCESS model 8).

Figure 1. Mediation model from Study 1. Values represent unstandardized regression coefficients and the parenthesized value represents the direct effect (i.e., the total effect controlling for the indirect effect), dashed paths indicate p > .05.



Study 2

Study 2 was conducted to replicate Study 1 with a different population (i.e., Mechanical Turk workers) and to allow for a longitudinal test of mediation using a two-wave, cross-lagged design (see the preregistration plan here: https://osf.io/8z3ch/). In

addition, sleep quality was assessed over both the past month (as in Study 1) and over the past two weeks in order to assess whether the time frame of assessment substantively affected our results.

Deviations from Preregistration

Our preregistration plan called for a sample size of 200 participants. We collected data from 471 participants, in order to account for substantial attrition between waves 1 and 2. Only 61 participants completed the second wave of this study, which required us to abandon our preregistered plan to test for longitudinal mediation using a cross-lagged panel model. Instead, Study 2 sought to replicate Study 1's cross-sectional analyses and data from the second wave were not analyzed. As such, all analyses should be viewed as exploratory and not confirmatory.

Materials and Methods

Due to recent evidence of artificial participants present in Mechanical Turk workers, we screened out all participants who did not pass an attention check that instructed them to select a specific number from an array. Doing so eliminated 154 responses from our original sample of 471.

Participants

Participants were 317 Mechanical Turk workers: 136 females, 181 males; age *M* = 33.15, *SD* = 11.18, range 18-85. Participants also reported their ethnic-racial identities: 85 Hispanic, 232 non-Hispanic; 17 American Indian, 82 Asian, 18 Black, 190 White, 7 Multiracial, 3 Other. We sought to obtain a sample size similar to Study 1. Participants received $0.50 for their participation in each wave of the study.

Procedure

Participants accessed the study on their personal computers by clicking an internet link to an online survey that was ostensibly to examine participants' ability to imagine fictitious events. After providing informed consent, participants completed a version of the PSQI that asked about their sleep over the past two weeks (to examine whether the timeframe of the sleep quality had an effect). Then, participants completed the Voodoo Doll Aggression Task, with a 'person that you are very angry towards' as the target. Finally, participants completed a battery of questionnaires that included the Positive Affect During Aggression Scale and the 1-month PSQI (as in Study 1). Embedded in the battery of questionnaires was an attention check item, which instructed participants to select a specific number from a number array.

Results

Descriptive Statistics

Descriptive statistics are summarized in Table 3.

Table 3. Descriptive statistics for all variables in Study 2. PADAS = Positive Affect During Aggression Scale, PSQI = Pittsburgh Sleep Quality Index, VDAT = Voodoo Doll Aggression Task.

Measure	*M*	*SD*	Range	*α*	Missing
PADAS	4.18	1.78	1 - 7	.96	0
PSQI (2-weeks)	7.87	3.90	0 - 18	.69	17
PSQI (1-month)	6.89	3.89	0 - 17	.72	41
VDAT	1.04	0.66	0 - 1.72	n/a	6

Correlations with Overall Poor Sleep Quality

Zero-order correlations between all study variables are summarized in Table 4. In line with our predictions, and unlike Study 1, poor sleep quality assessments over the past two weeks and one month were associated with greater aggression and aggressive pleasure.

*Table 4. Zero-order correlations between variables in Study 2. Gender coded as male = 1, female = -1. PADAS = Positive Affect During Aggression Scale, PSQI = Pittsburgh Sleep Quality Index, VDAT = Voodoo Doll Aggression Task. *p < .05, **p < .01, ***p < .001.*

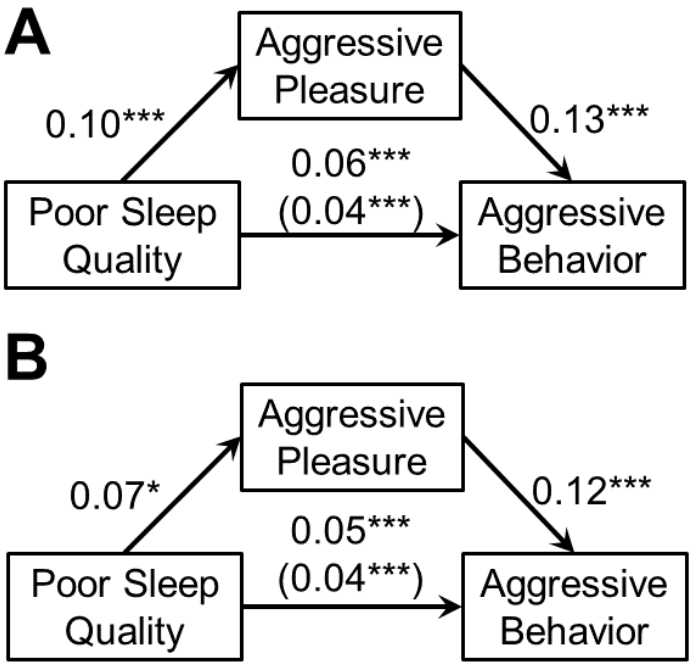
	Gender	PADAS	PSQI (2-Weeks)	PSQI (1-Month)
PADAS	.13*			
PSQI (2-Weeks)	.06	.20***		
PSQI (1-Month)	-.05	.16**	.89***	
VDAT	.19**	.39***	.33***	.30***

Mediation Modeling

Mediation modeling was performed in an identical fashion to Study 1, excepting that the 2-week version of the PSQI was used instead of the 1-month, as this measure had larger associations with the proposed mediator. Participants with any missing data were excluded from subsequent moderated mediation modeling, resulting in a final sample of N = 294. This overall model explained a significant amount of variance in aggression, R^2 = .23, $F(2, 291) = 1$, $p < .001$. Unlike Study 1, we observed the predicted indirect effect whereby aggressive pleasure mediated the effect of poor sleep quality on aggression, B = 0.08, SE = 0.03, 95% CI = 0.03, 0.13 (Figure 2A).

Using 1-month PSQI scores, the overall model explained a significant amount of variance in aggression, R^2 = .20, $F(2, 268) = 33.71$, $p < .001$. Again, we observed the predicted indirect effect whereby aggressive pleasure mediated the effect of poor sleep quality on aggression, $B = 0.05$, $SE = 0.02$, 95% $CI = 0.01, 0.11$ (Figure 2B).

Figure 2. Cross-sectional mediation models from Study 2 using (A) 2-week and (B) 1-month measures of sleep quality. Values represent unstandardized regression coefficients and the parenthesized value represents the direct effect (i.e., the total effect controlling for the indirect effect), dashed paths indicate p > .05.



Study 3

Study 3 was conducted to perform a longitudinal test of mediation using a two-wave, cross-lagged design (see the preregistration plan here: https://osf.io/ehjdp/).

Deviations from Preregistration

Our preregistration plan called for a sample size of 200 participants. We collected

data from 379 participants, in order to account for substantial attrition between waves 1 and 2.

Materials and Methods

Participants

Participants were 379 undergraduates enrolled in an introductory psychology course: 247 females, 123 males, 4 other, 5 missing gender data; age *M* = 19.15, *SD* = 2.97, range 18-47. Participants also reported their ethnic-racial identities: 54 Hispanic, 320 non-Hispanic, 5 missing ethnicity data; 2 American Indian, 4 Arab American, 47 Asian, 106 Black, 33 Multiracial, 161 White, 21 Other, 5 missing race data. Of these individuals, 222 participants completed the second wave: 149 females, 72 males, 1 missing gender data; age *M* = 19.31, *SD* = 3.65, range 18-47; 36 Hispanic, 185 non-Hispanic, 1 missing ethnicity data; 2 American Indian, 3 Arab American, 24 Asian, 60 Black, 19 Multiracial, 100 White, 13 Other, 1 missing race data. We sought to obtain a sample size close to Study 1. Participants received research credit towards their class's research requirement for their participation.

Procedure

Participants accessed both waves of the study on their personal computers by clicking an internet link to an online survey that was ostensibly to examine participants' ability to imagine fictitious events.

First wave. After providing informed consent, participants completed the 2-week version of the PSQI and then completed the Voodoo Doll Aggression Task, with a 'person that you are very angry towards' as the target. Finally, participants completed a battery of questionnaires that included the Positive Affect During Aggression Scale and

the 1-month version of the PSQI. Embedded in the battery of questionnaires was one attention check items, which instructed participants to select a specific number from a number array. Participants then provided their email addresses and were contacted 14 days later with instructions on how to complete the second wave of the study.

Second wave. Participants began the second wave by completing the 2-week version of the PSQI and were then randomly assigned to be either socially rejected or accepted via the Cyberball paradigm. After completing Cyberball, participants reported their feelings of social distress via the Need Threat Scale and then completed the Voodoo Doll Aggression Task, with one of their Cyberball partners as the target. Finally, participants completed a battery of questionnaires that included the Positive Affect During Aggression Scale and the 1-month version of the PSQI. Embedded in the battery of questionnaires were two attention check items, which instructed participants to select a specific number from a number array.

Results

Descriptive Statistics

Thirty one participants failed the attention check from the first wave and were screened out of all analyses pertaining to the first wave, final first wave N = 348. Six participants failed either or both of the attention checks from the second wave and were screened out of all analyses pertaining to the second wave, final second wave N = 216. Combined, 208 participants completed both waves and passed all three attention checks. These participants completed the second wave between 14 and 42 days after the first wave, M = 18.89 days, SD = 6.24, mode = 14 days (21.6% of the sample). Descriptive statistics are summarized in Table 5.

Table 5. Descriptive statistics for all variables in Study 3. Means (M) and standard deviations (SD) are presented for each Cyberball condition and for the combined, overall sample. NTS = Need Threat Scale, PADAS = Positive Affect During Aggression Scale, PSQI = Pittsburgh Sleep Quality Index, VDAT = Voodoo Doll Aggression Task. Parenthesized values represent the wave the data was obtained from: I = first wave, II = second wave.

	Accepted *N* = 99		Rejected *N* = 109		Overall				
Measure	*M*	*SD*	*M*	*SD*	*M*	*SD*	Range	*α*	*N*
PADAS (I)	-	-	-	-	2.81	1.79	1-7	.96	348
PSQI (2-Weeks; I)	-	-	-	-	7.20	3.29	1-17	.64	321
PSQI (1-Month; I)	-	-	-	-	6.65	3.59	0-18	.71	317
VDAT (I)	-	-	-	-	0.79	0.64	0-1.72	n/a	308
NTS (II)	2.51	0.55	3.42	0.71	2.98	0.78	1.11-4.9	.93	215
PADAS (II)	2.66	1.78	2.54	1.51	2.60	1.64	1-7	.95	215
PSQI (2-Weeks; II)	6.48	3.14	6.14	3.37	6.30	3.26	0-17	.64	198
VDAT (II)	0.28	0.54	0.46	0.61	0.37	0.59	0-1.72	n/a	213

Group Comparisons

Validating our rejection manipulation, rejected participants (coded as 1) reported greater social distress, $t(213) = 10.45$, $p < .001$, $d = 1.43$, 95% *CI* = 1.13, 1.73, compared to accepted participants (coded as -1). Rejected participants also stuck more pins in the voodoo doll that represented one of their Cyberball partners, $t(211) = 2.28$, $p = .024$, $d = 0.31$, 95% *CI* = 0.04, 0.58.

Correlations

Zero-order correlations between all study variables are summarized in Table 6. Poor sleep quality was associated with greater aggression, though only within the first wave. Poor sleep quality was unassociated with aggressive pleasure across both waves. Aggressive pleasure exhibited little within-person change between the two waves, $t(207) = 0.03$, $p = .980$, d = 0.00, 95% CI = -0.19, 0.19.

*Table 6. Zero-order correlations between variables from Study 3. Gender coded as male = 1, female = -1. NTS = Need Threat Scale, PADAS = Positive Affect During Aggression Scale, PSQI = Pittsburgh Sleep Quality Index, VDAT = Voodoo Doll Aggression Task. *p < .05, **p < .01, ***p < .001. Parenthesized values represent the wave the data was obtained from: I = first wave, II = second wave.*

	1	2	3	4	5	6	7	8
1. Gender (I)								
2. NTS (II)	.02							
3. PADAS (I)	.14*	.10						
4. PADAS (II)	.10	-.15*	.28***					
5. PSQI (2-weeks; I)	-.19**	-.03	-.04	-.10				
6. PSQI (2-weeks; II)	-.16*	.10	.08	-.17*	.56***			
7. PSQI (1-month; I)	-.19**	.00	.02	-.06	.87***	.49***		
8. VDAT (I)	.06	.06	.04	-.06	.19**	.12	.25***	
9. VDAT (II)	-.04	.39***	.18**	.03	.01	.02	.07	.31***

Within the second wave, the association between poor sleep quality and aggression was not moderated by being socially-rejected, $B = -0.01$, 95% $CI = -0.03$, 0.02, $SE = 0.01$, $t(192) = -0.57$, $p = .573$. The association between poor sleep quality

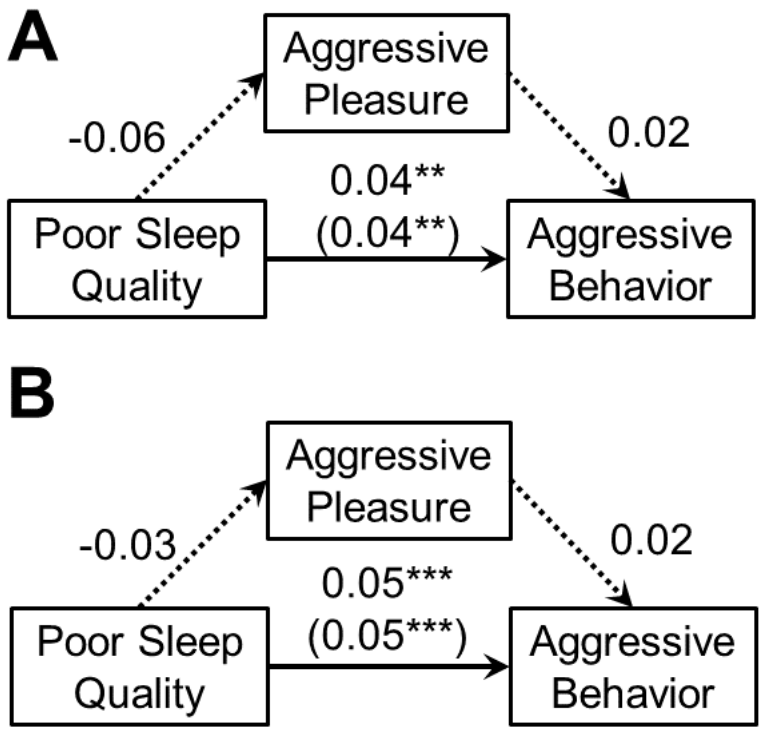
and aggressive pleasure was also not moderated by Cyberball condition, *B* = -0.03, 95% *CI* = -0.11, 0.04, *SE* = 0.04, *t*(194) = -0.83, *p* = .406.

Cross-Sectional Mediation Modeling

In an attempt to replicate the cross-sectional mediation models of the previous two studies, data from the first wave were entered into an identical analysis. Using 2-week PSQI scores, the overall model explained a significant amount of variance in aggression, R^2 = .04, *F*(2, 282) = 5.51, *p* = .005. However, no evidence of an indirect effect of greater aggressive pleasure was observed, *B* = -0.01, *SE* = 0.01, 95% *CI* = -0.03, 0.01 (Figure 3A). This null indirect effect was not moderated by Cyberball condition, *B* = 0.00, *SE* = 0.01, 95% *CI* = -0.02, 0.01.

Using 1-month PSQI scores, the overall model explained a significant amount of variance in aggression, R^2 = .07, *F*(2, 278) = 9.73, *p* < .001. However, no evidence of an indirect effect of greater aggressive pleasure was observed, *B* = 0.00, *SE* = 0.01, 95% *CI* = -0.02, 0.01 (Figure 3B). This null indirect effect was not moderated by Cyberball condition, *B* = 0.00, *SE* = 0.01, 95% *CI* = -0.02, 0.00.

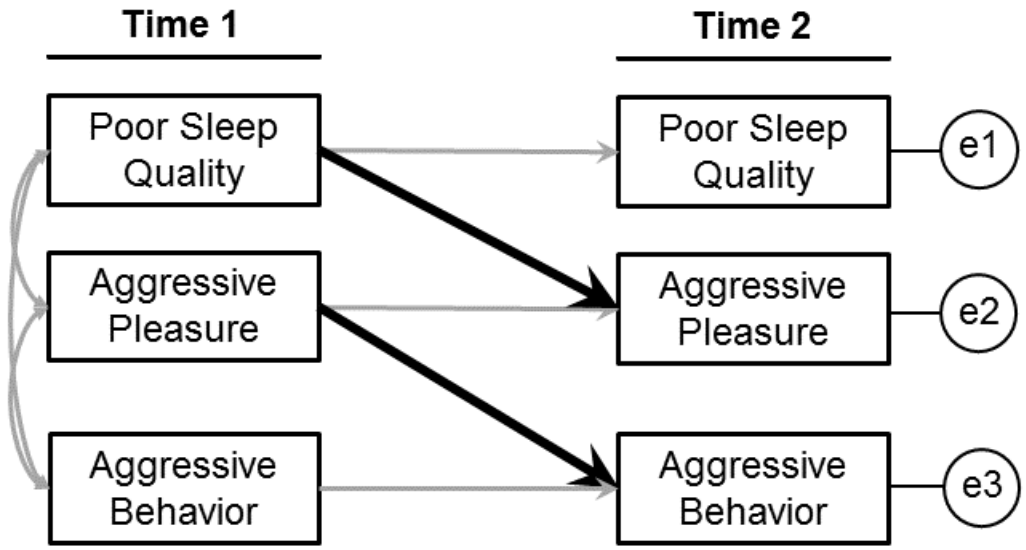
Figure 3. Cross-sectional mediation models from Study 3 using (A) 2-week and (B) 1-month measures of sleep quality. Values represent unstandardized regression coefficients and the parenthesized value represents the direct effect (i.e., the total effect controlling for the indirect effect), dashed paths indicate p > .05.



Time-Lagged Mediation Modeling

To longitudinally examine whether aggressive pleasure mediates the relationship between poor sleep quality and aggressive behavior, we employed autoregressive cross-lagged panel modeling to estimate mediation (as detailed by Preacher, 2015; Selig & Little, 2012; see Figure 4 for a rendering of the model).

Figure 4. Rendering of all variables and paths used to model longitudinal mediation in Study 3. Black paths indicate a and b paths of the predicted indirect effect. The variables e1-e3 represent residualized error variance of each wave II variable.



Such an approach estimates the existence of reciprocal and isolated associations between constructs over time, while accounting for their own auto-correlations. Fully-saturated, cross-lagged panel models were fit with maximum likelihood estimation of intercepts and slopes using AMOS software for SPSS, v.24.0. Models were fit with 2-week PSQI scores, PADAS scores, and log-transformed VDAT scores at both timepoints. Wave 1 variables were allowed to covary. Parameter estimates from the model are summarized in Table 7.

Table 7. Standardized parameter estimates from the cross-lagged models of Study 3. Separate estimates are presented for the 2-week and 1-month PSQI measures, collapsing across Cyberball conditions. PSQI = Pittsburgh Sleep Quality Index.

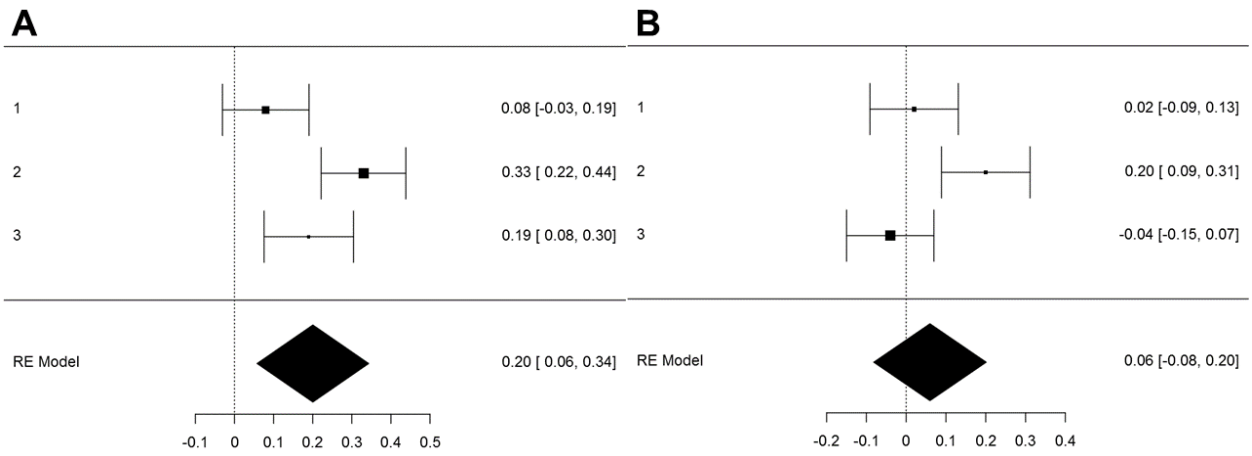
	2-Week PSQI			1-Month PSQI		
Path	*β*	*t*	*p*	*β*	*t*	*p*
T1 Sleep --> T2 Sleep	.60	10.14	< .001	.49	7.61	< .001
T1 Sleep --> T2 Pleasure	-.15	-2.14	.033	-.09	-1.31	.191
T1 Pleasure --> T2 Pleasure	.29	4.44	< .001	.29	4.40	< .001
T1 Pleasure --> T2 Pins	.16	2.44	.015	.16	2.42	.015
T1 Pins --> T2 Pins	.31	4.59	< .001	.31	4.58	< .001

All autocorrelations were robust and significant (Table 7). Aggressive pleasure during the first wave was positively associated with greater aggressive behavior in the second wave, showing a remarkable lack of change between timepoints, $t(207) = 0.03$, $p = .980$, $d = 0.00$, 95% *CI* = -0.16, 0.16. The inverse did not hold true (i.e., greater aggressive behavior during the first wave was unassociated with aggressive pleasure during the second wave). However, poor sleep quality during the first wave was *negatively* associated with aggressive pleasure during the second wave, though this effect was only observed for the 2-week version of the PSQI and not the 1-month version. These findings do not suggest the presence of our predicted indirect effect. These results did not support our predictions if run separately for each Cyberball condition.

Internal Meta-Analysis

An internal, random-effects meta-analysis across the three studies' zero-order correlations between poor sleep quality (1-month version for Study 1; 2-week version for Studies 2-3), aggressive pleasure, and aggressive behavior was performed using JASP v.9.0. Using restricted maximum likelihood estimation, we observed a modest correlation between poor sleep quality and aggressive behavior, r = .20, SE = 0.07, 95% CI = .06, 34, Z = 2.75, p = .006 (Figure 6A). These effects exhibited significant heterogeneity, $Q(2)$ = 10.09, p = .006. Conversely, we observed no correlation between poor sleep quality and aggressive pleasure, r = .06, SE = 0.07, 95% CI = -.08, .02, Z = 0.83, p = .407 (Figure 6B). These effects exhibited significant heterogeneity, $Q(2)$ = 9.78, p = .008. Readers should interpret internal meta-analyses with caution, as some questionable research practices (e.g., flexible data collection stopping rules) can inflate type I error rates in these analyses (Ueno, Fastrich, & Murayama, 2016). As such, these meta-analytic findings should be considered tenuous.

Figure 6. Internal meta-analyses of the correlation between poor sleep quality and (A) aggressive behavior and (B) aggressive pleasure.



Discussion

Modern-day amenities and demands may be undermining our species' progress at eliminating violence. Smartphones, email, and energy shots are all examples of 21st century innovations that increase productivity, yet they also undermine a fundamental human need: high-quality sleep (e.g., Demirci, Akgönül, & Akpinar, 2015). Such poor sleep quality has been previously linked to greater aggressive behavior (Kamphuis et al., 2012; Krizan & Herlache, 2016), yet how sleep quality influences such hostility remains poorly understood. In this paper, we sought to identify a potential mechanism through which poor sleep quality might increase aggression: the pleasure of harming others.

Sleep Quality and Interpersonal Harmony

Across three studies and over 900 participants, we replicated the association between poor sleep quality and aggressive behavior in a non-clinical sample of young adults (e.g., Gilbert et al., 2015). These findings add further support for the critical role of sleep quality in harmonious interpersonal functioning and emphasizes the need for more work to be done to understand how sleep promotes adaptive social processes (Gordon et al., 2017).

Sleep Quality and Sweet Revenge?

We attempted to build upon the link between sleep quality and aggression, testing whether this effect can be explained, in part, by greater reports of pleasure experienced during the aggressive act. However, we found no association between poor sleep quality and aggressive pleasure across our three studies. Cross-sectional mediation models identified a significant indirect effect in only one out of three tests. As the final nail in the coffin, a cross-lagged mediation model revealed evidence for an

indirect effect in the opposite direction of our prediction, whereby poor sleep quality predicted *decreased* aggressive pleasure. It may be that poor sleep quality is longitudinally-linked to reduced aggressive pleasure, a relationship that does not appear in cross-sectional data, though a theoretical explanation for this potential distinction is currently lacking. As such, there is no compelling evidence for our mechanistic predictions regarding aggressive pleasure.

The two studies that failed to find evidence for our predicted indirect effect recruited undergraduate students, whereas the study that did yield evidence for our predictions consisted of Mechanical Turk workers. Mechanical Turk workers differ from undergraduates in many ways. For instance, they are less ethnically and racially diverse and older (Paolacci & Chandler, 2014). It may be that our predictions hold for non-undergraduate samples, yet there is no theoretically-compelling reason for why this would be the case. Future work with other sampling populations could examine whether our null results are an artifact of employing undergraduate samples.

Social Rejection as a Contextual Factor

Using the Cyberball rejection paradigm, we replicated the ability of social rejection to increase social distress (Williams, 2009) and increase aggressive behavior (Chester & DeWall, 2017). However, rejection did not moderate the associations between sleep quality and aggression. This lack of moderation may have been due to low statistical power to detect an actual moderating effect or that rejection was a poor form of provocation to test our hypotheses. Other provocations, such as insults, frustrating tasks, and jealousy inductions may be better able to elicit greater anger and other forms of aggressive affect among individuals who experienced poor sleep quality.

Alternatively, poor sleep quality may simply promote both retaliatory and non-retaliatory forms of aggression to equal degrees. As such, poor sleep quality may not increase aggression purely by dysregulating affective responses to provocations such as social rejection, but may dispose individuals to be generally aggressive.

Rejection was also not found to moderate the null association between poor sleep quality and aggressive pleasure. As such, it was not the case that poor sleep quality renders specific forms of aggression to be more or less pleasant. Across both retaliatory and non-retaliatory forms of aggression, our hypotheses did not hold true. It may be that social rejection, as opposed to some other form of interpersonal provocation (e.g., insults), may have been unable to elicit our predicted aggressive pleasure. Yet previous work suggests that rejection and the Cyberball paradigm elicit strong associations between aggression and positive affect (Chester & DeWall, 2017).

A Reinforcement Model of Aggression

Irrespective of sleep quality, our findings may have some implications for our understanding of aggression. According to the reinforcement model of aggression, the positive affect and reward associated with aggressive acts buttress aggressive tendencies, increasing their likelihood in the future (Chester, Lynam, Milich, & DeWall, 2018). In Study 3, aggressive pleasure during the first wave predicted greater aggressive behavior during the second wave. This finding supports the reinforcement model, suggesting that the pleasure of aggressive acts can promote them over time. Further, we found that aggressive pleasure exhibited substantial test-retest reliability, which supports the psychometric suitability of the Positive Affect During Aggression Scale (Chester et al.,, in press). This autocorrelation suggests that aggressive pleasure

is temporally stable, which supports the construal of aggressive pleasure as a trait-like construct in which rank-order differences between individuals are moderately consistent over time. Those who seek to intervene upon aggression, in the context of sleep quality or without, may benefit from examining the reinforcing mechanisms of this behavioral phenotype.

Limitations and Future Directions

The aggressive pleasure mechanism that we outlined in this study is hardly exhaustive or exclusive of other mechanisms that promote the link between poor sleep quality and aggression. Indeed, there are likely many mechanisms through which poor sleep quality magnifies aggression (e.g., impaired self-regulation; Hagger, 2010). There are also many other variables that may affect our targeted mechanism: aggressive pleasure. Effects of such variables that were not included in this investigation may then feed forward to undermine subsequent sleep quality. For instance, interpersonal provocation (e.g., insults) can magnify aggressive pleasure (Chester & DeWall, 2016). Provoked individuals may then lie awake at night fantasizing about the pleasure of revenge, a cognitively arousing experience that may interfere with obtaining high-quality sleep. These effects could be recursive, magnifying each other over time, unless effectively regulated at varying psychological levels. According to the process model of emotion-regulation (Gross, 1998), individuals who are able to regulate the antecedents of and responses to such affectively-evocative experience as provocation will be able to end these potential recursive effects on aggressive pleasure and sleep quality. For instance, if individuals are able to reappraise their interpretation of the provocative event, then this may prevent increases in aggressive pleasure and its potential ability to

undermine sleep quality. Future work will benefit from modeling these recursive and regulatory affective processes across multiple timepoints.

There were limitations in our measurement approach. Our sleep quality measure employed the standard PSQI instructions and asked participants to report on the past month or past two weeks of sleep-related variables. Although these timeframes of retrospective recall has been validated numerous times via the PSQI (Buysse et al., 1989), it is possible that recall bias could have influenced our results. Additional work is needed to assess whether shorter timeframes (e.g., the night before) or longer timeframes (e.g., six months, one year) may affect these findings. Additionally, we measured and did not manipulate sleep quality, and therefore we cannot be certain that sleep quality has a causal effect on our study variables or that the direction of our effects do not exist in reverse: aggressive behavior promotes poorer sleep quality (as observed in Brissette & Cohen, 2002). In the future, experimental manipulations such as sleep deprivation techniques, and time-lagged, longitudinal designs could be used to establish directional and causal inferences regarding our mediation model. Further, researchers could use experimental manipulations of sleep and potential affective mechanisms to establish the temporal sequence of these psychological processes and the direction of their associations.

Our use of one aggression measure (i.e., the Voodoo Doll Aggression Task) may have been insufficient to the task. The task measures aggression symbolically, instead of allowing participants to believe they are actually harming another person. However, individuals tend to believe that the task causes some level of real harm (Chester et al., in press). Yet future work should employ multiple aggression measures to examine the

robustness of sleep effects across these operationalizations. Finally, we measured aggressive pleasure using a self-report questionnaire that is potentially affected by social desirability and other self-report bias concerns. Other measures of aggressive pleasure (e.g., neuroimaging of reward circuitry) should be used to circumvent this issue.

Conclusions

Individuals who suffer from poor sleep are often portrayed as belligerent and aggressive. This depiction has some evidentiary basis, as multiple studies have shown a clear link between poor sleep quality and greater aggression. In an attempt to identify a mechanism underlying this link between poor sleep and greater aggression, we found no evidence that suggests that sleep quality promotes aggression by magnifying the pleasure of the act. Such mechanistic investigations are hopefully useful in providing added granularity to research on sleep and aggression and may suggest avenues for future aggression reduction.

Acknowledgments

Research reported in this publication was supported by the National Institute on Alcohol Abuse and Alcoholism (NIAAA) and the National Institute on Aging (NIA) of the National Institutes of Health under award numbers K01AA026647 (PI: Chester) and K23AG049955 (PI: Dzierzewski).

References

Anderson, C. A., & Bushman, B. J. (2002). Human aggression. *Annual Review of Psychology*, *53*, 27-51.

Barrett, L. F., & Bliss-Moreau, E. (2009). Affect as a psychological primitive. *Advances in Experimental Social Psychology*, *41*, 167-218.

Benedict, C., Brooks, S. J., O'daly, O. G., Almèn, M. S., Morell, A., Åberg, K., ... & Larsson, E. M. (2012). Acute sleep deprivation enhances the brain's response to hedonic food stimuli: an fMRI study. *The Journal of Clinical Endocrinology & Metabolism*, *97*, E443-E447.

Berkowitz, L. (1982). Aversive conditions as stimuli to aggression. *Advances in Experimental Social Psychology*, *15*, 249-288.

Brissette, I., & Cohen, S. (2002). The contribution of individual differences in hostility to the associations between daily interpersonal conflict, affect, and sleep. *Personality and Social Psychology Bulletin*, *28*, 1265-1274.

Buckels, E. E., Jones, D. N., & Paulhus, D. L. (2013). Behavioral confirmation of everyday sadism. *Psychological Science*, *24*, 2201-2209.

Buysse, D. J., Reynolds III, C. F., Monk, T. H., Berman, S. R., & Kupfer, D. J. (1989). The Pittsburgh Sleep Quality Index: A new instrument for psychiatric practice and research. *Psychiatry Research*, 28, 193-213.

Carney, C. E., Edinger, J. D., Myer, B., Lindman, L., & Istre, T. (2006). Daily activities and sleep quality in college students. *Chronobiology International*, 23, 623-637.

Carskadon, M. A., & Dement, W. C. (2011). Normal human sleep: An overview. In M. H. Kryger, T. Roth, & W. C. Dement (Eds.), *Principles and practice of sleep medicine* (pp. 16-29). St. Louis, MI: Elsevier.

Chester, D. S. (2017). The role of positive affect in aggression. *Current Directions in Psychological Science, 26*, 366-370.

Chester, D. S. & DeWall, C. N. (2016). The pleasure of revenge: Retaliatory aggression arises from a neural imbalance toward reward. *Social Cognitive and Affective Neuroscience, 11*, 1173-1182.

Chester, D. S. & DeWall, C. N. (2017). Combating the sting of rejection with the pleasure of revenge: a new look at how emotion shapes aggression. *Journal of Personality and Social Psychology*, *112*, 413-430.

Chester, D. S., DeWall, C. N., & Enjaian, B. (in press). Sadism and aggressive behavior: Inflicting pain to feel pleasure. *Personality and Social Psychology Bulletin*.

Chester, D. S. & Lasko, E. N. (in press). Validating a standardized approach to the Taylor Aggression Paradigm. *Social Psychological and Personality Science*.

Chester, D. S., Lynam, D. R., Milich, R., & DeWall, C. N. (2018). Neural mechanisms of the rejection-aggression link. *Social Cognitive and Affective Neuroscience, 13*, 501-512.

Demirci, K., Akgönül, M., & Akpinar, A. (2015). Relationship of smartphone use severity with sleep quality, depression, and anxiety in university students. *Journal of Behavioral Addictions*, *4*, 85-92.

Dzierzewski, J. M., Dautovich, N., & Ravyts, S. (2018). Sleep and Cognition in the Older Adult. *Sleep Medicine Clinics,* 13, 93-106.

Dzierzewski, J. M., Mitchell, M., Rodriguez, J. C., Fung, C. H., Jouldjian, S., Alessi, C. A., & Martin, J. L. (2015). Patterns and predictors of sleep quality before, during and after hospitalization in older adults. *Journal of Clinical Sleep Medicine*, 11, 45-51.

Eadeh, F. R., Peak, S. A., & Lambert, A. J. (2017). The bittersweet taste of revenge: On the negative and positive consequences of retaliation. *Journal of Experimental Social Psychology*, *68*, 27–39.

Gilbert, L. R., Pond Jr, R. S., Haak, E. A., DeWall, C. N., & Keller, P. S. (2015). Sleep problems exacerbate the emotional consequences of interpersonal rejection. *Journal of Social and Clinical Psychology*, *34*, 50-63.

Gordon, A. M., & Chen, S. (2014). The role of sleep in interpersonal conflict: do sleepless nights mean worse fights? *Social Psychological and Personality Science*, *5*, 168-175.

Gordon, A. M., Mendes, W. B., & Prather, A. A. (2017). The social side of sleep: Elucidating the links between sleep and social processes. *Current Directions in Psychological Science*, *26*, 470-475.

Gross, J. J. (1998). The emerging field of emotion regulation: An integrative review. *Review of General Psychology*, *2*, 271-299.

Gruber, R., & Cassoff, J. (2014). The interplay between sleep and emotion regulation: conceptual framework empirical evidence and future directions. *Current Psychiatry Reports*, *16*, 500.

Gujar, N., Yoo, S. S., Hu, P., & Walker, M. P. (2011). Sleep deprivation amplifies reactivity of brain reward networks, biasing the appraisal of positive emotional experiences. *Journal of Neuroscience*, *31*, 4466-4474.

Hagger, M. S. (2010). Sleep, self-regulation, self-control and health. *Stress and Health*, *26*, 181-185.

Harmon-Jones, E., & Sigelman, J. (2001). State anger and prefrontal brain activity: evidence that insult-related relative left-prefrontal activation is associated with experienced anger and aggression. *Journal of personality and social psychology*, *80*, 797-803.

Hayes, A. F. (2012). PROCESS: A Versatile Computational Tool for Observed Variable Mediation, Moderation, and Conditional Process Modeling (Version 2.0) [Software]. Available from http://www.afhayes.com/public/process2012.pdf

Ikeda, T., Nagai, T., Kato-Nishimura, K., Mohri, I., & Taniike, M. (2012). Sleep problems in physically disabled children and burden on caregivers. *Brain & Development*, 34, 223-229.

Ireland, J. L. & Culpin, V. (2006). The relationship between sleeping problems and aggression, anger, and impulsivity in a population of juvenile and young offenders. *Journal of Adolescent Health*, *38*, 649-655.

Kahn-Greene, E. T., Lipizzi, E. L., Conrad, A. K., Kamimori, G. H., & Killgore, W. D. (2006). Sleep deprivation adversely affects interpersonal responses to frustration. *Personality and Individual Differences*, *41*, 1433-1443.

Kamphuis, J., Dijk, D. J., Spreen, M., & Lancel, M. (2014). The relation between poor sleep, impulsivity and aggression in forensic psychiatric patients. *Physiology & Behavior*, *123*, 168-173.

Kamphuis, J., Meerlo, P., Koolhaas, J. M., & Lancel, M. (2012). Poor sleep as a potential causal factor in aggression and violence. *Sleep Medicine*, *13*, 327-334.

Kay, D. B. & Dzierzewski, J. M. (2015). Sleep in the context of healthy aging and psychiatric syndromes. *Sleep Medicine Clinics*, 10, 11-15.

Knutson, B., & Greer, S. M. (2008). Anticipatory affect: neural correlates and consequences for choice. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *363*, 3771-3786.

Krizan, Z., & Herlache, A. D. (2016). Sleep disruption and aggression: Implications for violence and its prevention. *Psychology of Violence*, *6*, 542.

Krystal, A. D. & Edinger, J. D. (2008). Measuring sleep quality. *Sleep Medicine*, *9*, S10-S17.

Lindberg, N., Tani, P., Appelberg, B., Naukkarinen, H., Rimón, R., Porkka-Heiskanen, T., & Virkkunen, M. (2003). Human impulsive aggression: a sleep research perspective. *Journal of Psychiatric Research*, *37*, 313-324.

Mauss, I. B., Troy, A. S., & LeBourgeois, M. K. (2013). Poorer sleep quality is associated with lower emotion-regulation ability in a laboratory paradigm. *Cognition & Emotion*, *27*, 567-576.

McCrae, C. S., Dzierzewski, J. M., McNamara, J. P., Vatthauer, K. E., Roth, A. J., & Rowe, M. A. (2014). Changes in sleep predict changes in affect in older caregivers of individuals with Alzheimer's dementia: A multilevel model

approach. *Journals of Gerontology Series B: Psychological Sciences and Social Sciences*, *71*, 458-462.

McCrae, C. S., McNamara, J. P., Rowe, M. A., Dzierzewski, J. M., Dirk, J., Marsiske, M., & Craggs, J. G. (2008). Sleep and affect in older adults: Using multilevel modeling to examine daily associations. *Journal of Sleep Research*, *17*, 42-53.

Meijer, A. M., Habekothe, H. T., & Van Den Wittenboer, G. L. H. (2000). Time in bed, quality of sleep and school functioning of children. *Journal of Sleep Research*, *9*, 145-154.

Meijer, A. M., Reitz, E., Deković, M., Van Den Wittenboer, G. L., & Stoel, R. D. (2010). Longitudinal relations between sleep quality, time in bed and adolescent problem behaviour. *Journal of Child Psychology and Psychiatry*, *51*, 1278-1286.

Ong, A. D., Kim, S., Young, S., & Steptoe, A. (2017). Positive affect and sleep: A systematic review. *Sleep Medicine Reviews*, *35*, 21-32.

Paolacci, G., & Chandler, J. (2014). Inside the Turk: Understanding Mechanical Turk as a participant pool. *Current Directions in Psychological Science*, *23*, 184-188.

Pilcher, J. J., Ginter, D. R., & Sadowsky, B. (1997). Sleep quality versus sleep quantity: relationships between sleep and measures of health, well-being and sleepiness in college students. *Journal of Psychosomatic Research*, *42*, 583-596.

Preacher, K. J. (2015). Advances in mediation analysis: A survey and synthesis of new developments. *Annual Review of Psychology*, *66*, 825-852.

Preacher, K. J., Rucker, D. D., & Hayes, A. F. (2007). Addressing moderated mediation hypotheses: Theory, methods, and prescriptions. *Multivariate Behavioral Research, 42*(1), 185-227.

Pressman, S. D., Jenkins, B. N., Kraft-Feil, T. L., Rasmussen, H., & Scheier, M. F. (2017). The whole is not the sum of its parts: Specific types of positive affect influence sleep differentially. *Emotion*, *17*(5), 778.

Rajaratnam, S. M., Barger, L. K., Lockley, S. W., Shea, S. A., Wang, W., Landrigan, C. P., ... & Epstein, L. J. (2011). Sleep disorders, health, and safety in police officers. *Journal of the American Medical Association*, *306*(23), 2567-2578.

Ramsawh, H. J., Stein, M. B., Belik, S., Jacobi, F., & Sareen, J. (2009). Relationship of anxiety disorders, sleep quality, and functional impairment in a community sample. *Journal of Psychiatric Research*, 43, 926-933. https://doi.org/10.1016/j.jpsychires.2009.01.009

Reid, G. J., Hong, R. Y., & Wade, T. J. (2009). The relation between common sleep problems and emotional and behavioral problems among 2-and 3-year-olds in the context of known risk factors for psychopathology. *Journal of sleep research*, *18*(1), 49-59.

Russell, J. A. (2003). Core affect and the psychological construction of emotion. *Psychological Review*, *110*, 145-172.

Selig, J. P., & Little, T. D. (2012). Autoregressive and cross-lagged panel analysis for longitudinal data. In B. Laursen, T. D. Little, & N. A. Card (Eds.), *Handbook of developmental research methods* (pp. 265-278). New York, NY, US: Guilford Press.

Semız, Ü. B., Algül, A., Başoğlu, C., Ateş, M. A., Ebrınç, S., Çetın, M., ... & Günay, H. (2008). The relationship between subjective sleep quality and aggression in male

subjects with antisocial personality disorder. *Turkish Journal of Psychiatry*, *19*, 1-9.

Shin, C., Kim, J., Yi, H., Lee, H., Lee, J., & Shin, K. (2005). Relationship between trait-anger and sleep disturbances in middle-aged men and women. *Journal of Psychosomatic Research*, *58*, 183-189.

Sin, N. L., Almeida, D. M., Crain, T. L., Kossek, E. E., Berkman, L. F., & Buxton, O. M. (2017). Bidirectional, temporal associations of sleep with positive events, affect, and stressors in daily life across a week. *Annals of Behavioral Medicine*, *51*(3), 402-415.

Soffer-Dudek, N., Sadeh, A., Dahl, R. E., & Rosenblat-Stein, S. (2011). Poor sleep quality predicts deficient emotion information processing over time in early adolescence. *Sleep*, *34*, 1499-1508

Stoia-Caraballo, R., Rye, M. S., Pan, W., Kirschman, K. J. B., Lutz-Zois, C., & Lyons, A. M. (2008). Negative affect and anger rumination as mediators between forgiveness and sleep quality. *Journal of Behavioral Medicine*, *31*, 478-488.

Thomsen, D. K., Mehlsen, M. Y., Christensen, S., & Zachariae, R. (2003). Rumination—relationship with negative mood and sleep quality. *Personality and Individual Differences*, *34*, 1293-1301.

Troxel, W. M., Robles, T. F., Hall, M., & Buysse, D. J. (2007). Marital quality and the marital bed: Examining the covariation between relationship quality and sleep. *Sleep Medicine Reviews*, *11*, 389-404.

Ueno, T., Fastrich, G., & Murayama, K. (2016). Meta-analysis to integrate effect sizes within a paper: possible misuse and Type-1 error inflation. *Journal of Experimental Psychology: General*, *145*(5), 643-654.

Vaughn, M. G., Salas-Wright, C. P., White, N. A., & Kremer, K. P. (2015). Poor sleep and reactive aggression: results from a national sample of African American adults. *Journal of Psychiatric Research*, *66*, 54-59.

Williams, K. D. (2009). Ostracism: A temporal need-threat model. *Advances in Experimental Social Psychology*, *41*, 275–314.

Williams, K. D., Cheung, C. T, K., & Choi, W. (2000). Cyberostracism: Effects of being ignored over the internet. *Journal of Personality and Social Psychology*, *79*, 748–762.

Williams, K.S., Yeager, D.S., Cheung, C.K.T., & Choi, W. (2012). Cyberball (Version 4.0) [Software]. Available from https://cyberball.wikispaces.com