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By

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Abstract

Emotion, Emotion Regulation, and Sleep Quality in Caregivers of Patients with Neurodegenerative Disease

by

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Doctor of Philosophy in Psychology

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Sleep is a vital biological function, necessary to physical and psychological health. Caregivers of patients with neurodegenerative disease suffer from chronically poor sleep. Research suggests that emotions can influence sleep quality, but little research has examined this relationship in caregivers of patients with neurodegenerative disease. In the present study, objective laboratory measures of emotion and emotion regulation, and a combination of prospectively-reported and objectively-measured sleep quality, were used to examine this important relationship.

Caregivers' physiological and expressive reactivity to emotion-eliciting films was measured in the laboratory. Caregivers' physiological reactivity to two emotion regulation tasks (suppression, amplification) was also measured. During the week following laboratory testing, caregivers wore an actigraphy wristwatch, which recorded movement and ambient light in order to measure sleep quality, and completed a daily sleep diary. Data were analyzed to test the hypotheses that (a) greater physiological reactivity and (b) greater expressive reactivity would be associated with worse sleep quality during the following week, and to determine whether physiological reactivity to the emotion suppression and amplification tasks was associated with sleep quality.

Sleep quality in the present study was largely similar to and for some measures, better than sleep in previously published samples of non-caregiver older adults. Results partially supported the hypothesis that greater physiological reactivity to the films would be associated with worse sleep quality. Greater physiological reactivity to a film chosen to elicit distress was associated with worse sleep quality, whereas greater physiological reactivity to a film chosen to elicit sexual arousal was associated with better sleep quality. Exploratory analyses revealed that the results were reliable across caregivers for two of the three largest neurodegenerative diagnostic groups in the sample, and across caregiver sex. Neither expressive reactivity to the films, nor physiological reactivity to the emotion suppression or amplification tasks, was associated with sleep quality. These findings indicate that caregivers' physiological reactivity to distressing and sexually arousing stimuli are associated with sleep quality. Interventions that reduce physiological reactivity to distressing stimuli, or that increase caregivers' physiological reactivity to sexually-arousing stimuli, may improve caregiver sleep and its downstream effects.

Introduction

Caregivers of patients with dementia and other neurodegenerative diseases encounter high levels of stress as they deal with the burdens of caregiving. Related to this stress (Roth, 2007), these caregivers often suffer from poor sleep quality (Creese, Bédard, Brazil, & Chambers, 2007; Wilcox & King, 1999). Despite the prevalence of sleep problems in caregivers and the associated health risks (Leng et al., 2015), there are several notable gaps in the existing research. These include the lack of research examining the role of emotion (e.g., individual differences in emotional reactivity and emotion regulation measured using objective laboratory methods) in caregiver sleep quality.

Importance of Sleep

Sleep is “a reversible condition of reduced responsiveness usually associated with immobility” (Cirelli & Tononi, 2008, p. 1605). The reversibility of sleep distinguishes it from coma; the quality of reduced responsiveness distinguishes it from wakefulness. Based on the observations that all animals sleep in some capacity, that sleep deprivation does not occur without an eventual compensatory rebound, and that sleep deprivation does not occur without negative consequences, sleep is judged to serve essential functions in all animal species (Cirelli & Tononi, 2008). The functions served across species are not fully understood, but the primary function is theorized to involve maintaining neural health at the cellular level, with many downstream benefits and possibly also with benefits unrelated to neural health (Cirelli & Tononi, 2008).

The term 'sleep quality' can refer to any of a wide range of qualities related to sleep (Harvey, Stinson, Whitaker, Moskowitz, & Virk, 2008; Ramlee, Sanborn, & Tang, 2017). In this thesis, I use "sleep quality" as an umbrella term to refer to sleep efficiency (i.e., the percentage of time in bed actually spent sleeping), wake after sleep onset (i.e., the number of minutes awake between falling asleep in the evening and final awakening in the morning), or total sleep time (i.e., the number of minutes asleep during the night). Unless otherwise noted, these indicators of sleep quality were measured using prospective self-report (i.e., sleep diaries completed each morning after waking), sleep actigraphy (i.e., a wristwatch with a motion sensor that records minute by minute over several days), or polysomnography (i.e., a multimodal approach that includes measures of brain activity, eye movement, heart rate, and breath during sleep).

Worse sleep quality is reliably associated with worse cognitive functioning and with greater risk of dementia (Ju, Lucey, & Holtzman, 2013). The link between sleep quality and dementia may be mediated by amyloid- β peptides, which are thought to contribute to Alzheimer's disease (Crimins, Pooler, Polydoro, Luebke, & Spires-Jones, 2013). In both mice and human beings, the concentration of amyloid- β peptides in cerebrospinal fluid fluctuate during the diurnal cycle, increasing during periods of wakefulness and decreasing during sleep. Amyloid- β peptide concentration is higher in mice with disrupted sleep than in those with better sleep quality; when sleep is chronically disrupted, amyloid- β form the plaques associated with Alzheimer's disease at a higher rate than occurs in sleep that is not chronically disrupted (Ju et al., 2013).

Given the link between sleep and neural health, it is not surprising that disruptions to sleep quality are also strongly associated with poor mental health. Poor sleep quality predicts episodes of depression and anxiety (Cox & Olatunji, 2016; Franzen & Buysse, 2008), and contributes to symptom relapse in people with bipolar disorder (Harvey, Talbot, & Gershon, 2009). Although the link between sleep and mental health is not yet fully understood, studies with rodents have shed some light on the matter. Chronic sleep restriction in rats has been shown

to desensitize the serotonin 1A receptor system and to blunt the ACTH response, for example (Novati et al., 2008; Roman, Walstra, Luiten, & Meerlo, 2005); both of these changes to the brain are consistent with depression in human beings (Bardeleben, Stalla, Müller, & Holsboer, 1988; Savitz, Lucki, & Drevets, 2009).

Poor sleep quality is also associated with numerous negative health outcomes. During normal sleep, levels of inflammatory stress hormones (such as cortisol and norepinephrine) in the blood stream decrease, and levels of hormones that promote cell growth (such as growth hormone and prolactin) increase. When sleep is chronically disrupted, the hypothalamus-pituitary-adrenal (HPA) axis and the sympathetic nervous system become more active, resulting in greater inflammatory and weaker antiviral responses throughout the body (Irwin, 2015). These responses have a number of health-related consequences, including reduced levels of lymphocyte cells in the blood (Savard, Laroche, Simard, Ivers, & Morin, 2003), higher risk of contracting diseases such as pneumonia and the common cold (Patel et al., 2012; Prather, Janicki-Deverts, Hall, & Cohen, 2015), and higher risk for cardiovascular disease including hypertension and venous thromboembolism (Chung et al., 2015; Meng, Zheng, & Hui, 2013). Sleep quality even affects vaccination effectiveness: vaccinations are less effective if the receiver has poor sleep quality the following night. Compared to those who had good sleep quality after immunization, immunologic responses to vaccines for influenza and for hepatitis A are reduced by approximately 50% in people with poor sleep quality after immunization (Lange, Perras, Fehm, & Born, 2003; Spiegel, Sheridan, & Van Cauter, 2002).

Due to the close links between sleep quality and numerous facets of health, factors that are related to individual differences in sleep quality are important and should be studied. Research into predictors of sleep quality may be especially important in vulnerable populations, such as the caregivers of patients with neurodegenerative disease, who are often elderly and report both poor sleep quality and high rates of physical and mental health problems (Creese et al., 2007; Pinquart & Sörensen, 2007).

Sleep Quality in Caregivers of Patients with Neurodegenerative Disease

Role of stress. Poor sleep quality is common when people are under stress. Higher work demands and workload, increases in the tasks of daily living, and lower social support are all associated with worse sleep quality (Åkerstedt et al., 2002). Sleep quality is worse following days with increased stress and worry (Åkerstedt, Kecklund, & Axelsson, 2007), and people who suffer from insomnia report worse sleep quality when they experience greater interpersonal distress than when they do not (Gunn, Troxel, Hall, & Buysse, 2014). In older adults, a greater tendency to ruminate over regrets is associated with worse sleep quality even when controlling for depression, medications, and medical conditions that affect sleep (Schmidt, Renaud, & Van der Linden, 2012). These studies indicate that across the adult lifespan and in a variety of situations, stress contributes to decrements in sleep quality.

Individuals under high levels of stress experience worse sleep quality largely because of the heightened physiological arousal associated with stress. During normal sleep, people experience significantly lower physiological arousal than they do while awake. Physiological changes associated with decreased sympathetic and increased parasympathetic nervous system activation occur: heart rate slows, blood pressure decreases, and cardiac pre-ejection period increases (Bonnet & Arand, 1995; Kerkhof, 1998; Riedijk et al., 2006; Takeuchi et al., 1994; Trinder et al., 2001). People with insomnia, however, experience hyperarousal (Creese et al., 2007; Roth, 2007; Wilcox & King, 1999). Their physiological arousal is higher than controls' throughout the day, before bed, and during non-rapid eye movement sleep (Bonnet & Arand,

1995; Hall et al., 2007; Irwin, 2015; Morin, Rodrigue, & Ivers, 2003; Roman et al., 2005; Xie et al., 2013). The physiological arousal that disrupts sleep quality in insomniacs seems at least partly due to stress and emotion; they report stressful events as having a higher impact on their sleep than do control participants, and tend to experience greater worry, stress, and rumination before bed (Creese et al., 2007; Morin et al., 2006; Wilcox & King, 1999). Indeed, the physiological activation and emotional arousal associated with worry are thought to contribute to and maintain insomnia (Harvey, 2002; Irwin, 2015; Roman et al., 2005; Xie et al., 2013). Higher physiological arousal from stress thus impedes the ability to fall asleep and remain asleep.

Stress and sleep quality in caregivers of patients with neurodegenerative disease.

Caregivers of patients with neurodegenerative disease are a population under high stress. They shoulder the physical burden of caring for an increasingly disabled person. Often they are simultaneously trying to cope with slowly losing a loved one and dealing with the patient's disruptive behaviors, apathy, depression, memory loss, suffering, and other symptoms (Dubois et al., 2007; Rascovsky et al., 2007). Caregiving for patients with neurodegenerative disease can thus be considered a source of chronic stress; indeed, evidence shows that being a caregiver increases stress hormones and weakens the immune system (Vitaliano, Zhang, & Scanlan, 2003). Consistent with this, nearly two-thirds of caregivers of patients with neurodegenerative disease experience depressive symptoms, and almost half meet a diagnostic threshold for clinical depression (Mausbach, Chattillion, Roepke, Patterson, & Grant, 2013; Papastavrou, Kalokerinou, Papacostas, Tsangari, & Sourtzi, 2007). These high rates of depression seem to be particular to caregivers of patients with neurodegenerative disease. Compared to caregivers of cancer patients, for example, caregivers of patients with neurodegenerative disease report lower rates of life satisfaction and positive affect, higher rates of stress, negative affect, and feeling alone, and are more likely to take anti-anxiety medication (Clipp & George, 2008).

Given the significant stress that caregivers of patients with neurodegenerative disease suffer, it is no surprise that they report poor sleep quality as well. In one sample of these caregivers, over half reported that their sleep was only either "fair" or "poor"; in another, over 75% reported at least one indicator of poor sleep quality in the previous month (Creese et al., 2007; Wilcox & King, 1999). Despite these findings, large gaps exist in the research on these caregivers' sleep quality. Caregivers of patients with neurodegenerative disease are found to have poor sleep quality when sleep quality is measured with subjective self-report (e.g., rating general sleep quality as "poor," "fair," "good," or "excellent") or retrospective self-report (e.g., reporting the times in the past month that they usually go to bed, wake up, etc.). However, little research has examined caregivers' sleep quality using prospective self-report (e.g., sleep diaries in which caregivers report the time they went to bed the previous night and the time they woke up that morning, over several days) or objective measures (e.g., sleep actigraphy, in which caregivers wear wristwatches with motion sensors that record minute by minute over several days, allowing researchers to infer when the caregivers were awake and when they were asleep). The distinction between subjective and retrospective self-report on one hand, and prospective self-report and objective measures on the other hand, is an important one: prospective self-report and objective measures of sleep quality are less subject to bias from mood or recall errors than are subjective or retrospective self-report, and thus are deemed more reliable (Smith & Wegener, 2003).

The extent to which caregivers of patients with neurodegenerative disease experience worse prospective self-reported or objectively-measured sleep quality remains unclear. Some studies have found little to no evidence of worse objective sleep quality in caregivers of patients

with neurodegenerative disease than in controls (Castro et al., 2009; McKibbin et al., 2005). Other research has found significant evidence for worse objective sleep quality in caregivers of patients with neurodegenerative disease, including lower sleep efficiency (the percentage of time in bed actually spent sleeping), and lower total sleep time compared to controls (Rowe, McCrae, Campbell, Benito, & Cheng, 2008). These contradictory results indicate that the degree to which caregivers' sleep is actually disrupted remains unknown.

Emotion and Sleep Quality

Objective individual differences in emotional reactivity and subjective trait emotion.

Finding factors that contribute to poor sleep quality in caregivers of patients with neurodegenerative disease is a necessary step toward understanding and eventually improving their sleep. One candidate is individual differences in caregivers' emotional reactivity (Gross, Sutton, & Ketelaar, 1998). Caregivers of patients with neurodegenerative disease experience a wide range of emotions while caring for their partner, including anger, sadness, fear, disgust, and happiness (Day & Anderson, 2011; Galvin et al., 2010; MacNeil et al., 2010; Rudd, Viney, & Preston, 1999; Stones, Hadjistavropoulos, Tuuko, & Kozma, 1995). Greater emotional reactivity generally involves greater physiological arousal, which is, as described above, an established source of sleep disruption. Thus, the physiological arousal associated with emotional reactivity in caregivers of patients with neurodegenerative disease may disrupt their sleep quality.

There have been only three studies on emotion and sleep in caregivers of patients with neurodegenerative disease to date, and each has used subjective measures of trait emotion (that is, self-report of how the participants usually feel). These three studies have shown the same general findings as the studies of healthy samples (Cacioppo et al., 2002; Kahn, Sheppes, & Sadeh, 2013; Kurina et al., 2006; Shin et al., 2005; Steptoe, O'Donnell, Marmot, & Wardle, 2008; Waters, Adams, Binks, & Varnado, 1993), namely, greater trait positive emotion is associated with better sleep quality, and greater trait negative emotion is associated with worse sleep quality. The first of the three caregiver studies found that caregivers of patients with neurodegenerative disease had greater trait negative affect and worse retrospectively self-reported sleep quality than controls, and in the combined sample of caregivers and controls, greater trait negative affect was associated with worse retrospectively self-reported sleep quality (Brummett et al., 2006). The second study found that greater trait positive affect and greater trait positive-to-negative-affect ratio was associated with better retrospectively self-reported, though not objectively-measured, sleep quality (Känel et al., 2013). The third study found that greater trait positive affect was associated with better retrospectively self-reported sleep quality among caregivers, but not among controls (Fredman, Gordon, Heeren, & Stuver, 2014).

In the context of negative emotions, the nature of the association between emotion and sleep quality seems to depend on whether emotion is measured subjectively or objectively, and as a trait or as a state. When negative emotion is measured objectively as a state in healthy samples, such as by experimentally inducing emotion just before sleep, the association between emotion and sleep disruption seems to be driven by physiological arousal. High-arousal state negative emotion before sleep (e.g., stress from believing the participant failed an intelligence test) is associated with worse sleep quality (Vandekerckhove et al., 2011), whereas low-arousal state negative emotion (e.g., sadness from listening to sad classical music) is associated with quicker sleep onset (Talbot, Hairston, Eidelman, Gruber, & Harvey, 2009). These results are consistent with the effect that stress-related physiological arousal has on sleep: greater physiological arousal disrupts sleep, whereas lower physiological arousal improves it. To date,

no research has examined the contribution of physiological arousal in the impact of objectively-measured positive emotion on sleep quality.

These studies of objective state negative emotion, which emphasize physiological arousal as a contributor to worse sleep quality, may help explain why the valence of trait emotion is associated with sleep quality when emotion is measured subjectively. Broadly speaking, positive emotion has a physiological undoing effect: it speeds physiological recovery from negative emotion, returning the body to a baseline level of physiological arousal (Fredrickson & Levenson, 1998; Fredrickson, Mancuso, Branigan, & Tugade, 2000). Greater trait positive emotion may shorten the duration of heightened physiological arousal from state negative emotion, and thus may improve sleep quality. Conversely, several (though not all) basic negative emotions are associated with greater physiological arousal (Ekman, Levenson, & Friesen, 1983). Greater trait negative emotion may cause higher physiological arousal over the course of days and weeks, and thus may disrupt sleep quality. This explanation would be consistent with the idea that greater physiological arousal impairs sleep quality.

To date, no studies of caregivers' emotion and sleep have used objective measures of individual differences in emotional reactivity (e.g., measuring physiological and behavioral responses to emotion-eliciting stimuli in a laboratory setting). Additionally, among studies of caregivers' emotion and sleep, the only study to measure caregivers' sleep objectively showed that emotion was associated with retrospective self-report but not objectively-measured sleep quality (Känel et al., 2013). Considering how few studies have examined emotion and sleep in caregivers of patients with neurodegenerative disease, as well as the use of subjective measures of emotion and subjective or retrospective self-report measures of sleep quality in these studies, the association between caregivers' emotion and sleep quality – especially using objective measures of individual differences in emotional reactivity, and sleep diary and objective measure of sleep quality– warrants further investigation.

Emotion regulation. Emotion regulation may also be associated with sleep quality in caregivers of patients with neurodegenerative disease. Emotion regulation is the process by which people modify the size and duration of their emotional reactions, including the degree of physiological arousal (Gross, 1998). If greater physiological arousal increases sleep disruption, as the literature suggests, then emotion regulation strategies that reduce physiological arousal would be expected to improve sleep quality, and regulation strategies that increase physiological arousal would be expected to worsen it.

The association between emotion regulation and sleep disruption has not been studied in caregivers of patients with neurodegenerative disease, but a small number of studies have examined it in healthy populations. These studies suggest that emotion regulation strategies that involve acknowledging or reappraising emotion, which reduce physiological arousal (Campbell-Sills, Barlow, Brown, & Hofmann, 2006), improve sleep quality. One study found that, after a stressful event, participants who were instructed to use “experiential” emotion regulation (i.e., acknowledging and expressing their emotional experience) experienced better objective sleep quality than participants who were instructed to use “cognitive analytical” emotion regulation (Vandekerckhove et al., 2012). Another study found that wives' greater disclosure of their thoughts and feelings to their husbands (a form of emotion regulation) was associated with better retrospective self-reported sleep quality (Kane, Slatcher, Reynolds, Repetti, & Robles, 2014). In another study, greater subjective difficulties with emotion regulation (including non-acceptance of emotion and lack of emotional clarity) were associated with worse retrospective self-report sleep quality (Şandru & Voinescu, 2014). And in another study, participants watched several

sadness-inducing films. They were instructed to “just watch” a film in a “baseline” condition, and to “think about the situation you see in a more positive light” for a film in a “reappraisal” condition, with participants reporting the intensity of their sadness after each film. Reappraisal ability was computed as the difference in sadness between the baseline condition and the reappraisal condition. Lower reappraisal ability was associated with worse retrospective self-report sleep quality (Mauss, Troy, & LeBourgeois, 2013).

Based on these studies, it appears that emotion regulation strategies that reduce physiological arousal can improve objective and retrospective self-reported sleep quality. Some emotion regulation strategies, however, increase physiological arousal. Emotion suppression, that is, inhibiting emotion expressive behavior, is one such strategy (Campbell-Sills et al., 2006; Gross, 2002). If caregivers of patients with neurodegenerative disease regularly use emotion suppression to conceal their emotion, then emotion suppression may well worsen caregivers’ sleep quality. No research to date has examined whether caregivers frequently use this strategy while interacting with the patients for whom they care, but anecdotally, some caregivers report attempting to hide their anger, frustration, and sadness from the patients. Emotion suppression may thus be salient to caregivers’ daily lives, and the physiological arousal elicited by emotion suppression may predict worse sleep quality. Alternately, like other forms of self-regulation (Baumeister, 2002), emotion regulation strategies like emotion suppression or amplification (that is, increasing the intensity of emotion expressive behavior) may deplete physiological and mental resources and may increase the need for rest, which could improve sleep quality. Examining the association between emotion regulation and sleep quality among caregivers of patients with neurodegenerative disease is important, and may eventually lead to interventions to improve sleep quality in caregivers of patients with neurodegenerative disease.

Aims and Hypotheses

Based on the literatures reviewed and the gaps identified above, this study has two specific aims, the first of which has two hypotheses and the second of which has two exploratory questions.

Aim 1: To investigate the association between objectively-measured emotional reactivity (i.e., physiological and expressive responses to emotion-eliciting films) and sleep quality in caregivers of patients with neurodegenerative disease.

Hypothesis 1a: Greater physiological reactivity to emotion-eliciting films will be associated with worse sleep quality during the following week.

Hypothesis 1b: Greater expressive reactivity to emotion-eliciting films will be associated with worse sleep quality during the following week.

Rationale: In the current study, physiological reactivity to emotion-inducing stimuli in the lab is conceptualized as an analog of physiological reactivity in daily life. Greater resting physiological arousal (during both wake and sleep periods) is associated with greater sleep disruption (Bonnet & Arand, 1997). Thus, greater physiological reactivity in the lab is expected to be associated with worse sleep quality.

As with physiological reactivity, in this study expressive reactivity in the lab is conceptualized as an analog of expressive reactivity in daily life. Greater expressive reactivity is modestly associated with greater physiological reactivity (Mauss, Levenson, McCarter, Wilhelm, & Gross, 2005), and greater physiological arousal is associated with greater sleep disruption (Bonnet & Arand, 1997). Additionally, expressive reactivity involves contraction of muscles in the face and

neck. Contraction of these muscles is associated with worse sleep quality as well (Freedman & Sattler, 1982). Thus, greater expressive reactivity in the lab is expected to be associated with worse sleep quality.

Aim 2: To investigate the association between physiological reactivity during emotion suppression and emotion amplification tasks and sleep quality in caregivers of patients with neurodegenerative disease.

Exploratory question 2a: Will physiological reactivity during an emotion suppression task be associated with caregivers' sleep quality?

Exploratory question 2b: Will physiological reactivity during an emotion amplification task be associated with caregivers' sleep quality?

Rationale: In the current study, physiological reactivity during emotion suppression and amplification tasks in the laboratory is conceptualized as an analog of physiological reactivity to emotion suppression and amplification in daily life. Being more physiologically aroused during emotion regulation (suppression, amplification) in the lab and in the real-world might indicate either : a) greater physiological reactivity during emotion regulation, or b) greater effort to regulate emotion. As discussed above, greater resting physiological arousal is generally associated with greater sleep disruption (Bonnet & Arand, 1997). Therefore, greater physiological reactivity during emotion regulation could be associated with worse sleep quality. Alternately, if the participants with manifest greater physiological arousal during emotion regulation are making a greater effort to regulate their emotions, they may experience a depletion of mental and physiological resources, which could result in increased pressure to sleep. Because of these two different possibilities, it seemed best to frame this aim in terms of exploratory research questions rather than particular hypotheses.

Methods

Participants

Forty spousal caregivers whose partners had been diagnosed with a neurodegenerative disease were recruited as part of a larger study of health and resilience of caregivers of patients with neurodegenerative disease, conducted by the Memory and Aging Center (MAC) at the University of California, San Francisco (UCSF) and the Berkeley Psychophysiology Laboratory (BPL). Caregivers' average age was 64.9 (*SD* 8.2). In terms of sex, 62.5% of the caregivers were female. In terms of relationship to the patients, 95% of the caregivers were married to the patients; the remaining 5% were unmarried romantic partners. Among the married spouses, average marriage length was 35.0 years (*SD* 15.7). Patients were diagnosed by a team of neurologists, neuropsychologists, and nurses at UCSF using structural MRI, neuropsychological testing, and clinical interview. Patients primarily met criteria for frontotemporal dementia (Rascovsky et al., 2011), probable Alzheimer's disease (McKhann et al., 2011), and progressive supranuclear palsy (Litvan et al., 1996). Patients who met criteria for "probable" Alzheimer's disease were included because a true diagnosis of Alzheimer's disease requires autopsy (McKhann et al., 2011); thus, "probable" Alzheimer's is the most confident diagnosis possible in living Alzheimer's patients. Patient diagnoses are presented in Table 1.

Procedure

Patients with a confirmed or probable neurodegenerative disease were recruited for a larger research study on neurodegenerative disease, involving three days of testing at the the MAC and one day of a laboratory assessment of emotional functioning at the BPL. Caregivers

also participated in the daylong assessment of emotional functioning at the BPL. The BPL session was scheduled as soon after the MAC assessment as possible (generally within two weeks).

On the morning of their session, the participants (the patient and the caregiver) came to the BPL, signed consent forms, and were led to separate laboratory suites. Each was seated in a comfortable chair with a 20-inch video monitor located at a distance of 24 inches. Experimenters applied physiological sensors to the participants' torso, hand, and ears to record physiological activity (see below for additional details).

Participants responded to questions on the television screen about their pre-trial emotional state, rating how intensely they felt each of 13 emotions on a 0-2 scale. This was followed by five emotional reactivity trials in which participants first were asked to watch a fixation point on a television screen for one minute (the "baseline" period) and then watched a brief (1-2 minute) film clip from a movie or television show. Each of these films was chosen to elicit a specific emotion (see description of film clips below and average emotion ratings in Table 2). After each film clip participants were asked to watch a second fixation point on the television screen for another minute. They then answered an open-ended question regarding their emotional experience during the film ("What emotion did you feel while watching the film?"), and then rated the same 13 emotions as before.

Between the third and fourth emotional reactivity trials, participants completed two emotion regulation trials. The emotion regulation trials were similar to the emotional reactivity trials, with the addition of regulation instructions before each baseline period. During the emotion regulation trials, participants were instructed either to "HIDE your reaction so that no one would know how you feel while watching the film" (suppression condition) or to "SHOW your reaction so that some one watching you would know exactly how you feel while watching the film" (amplification condition). As in the reactivity trials, they then were asked to watch a fixation point on the television screen for one minute (the "baseline" period). They then watched a brief (1-2 minute) film clip from a movie or television, both of which reliably elicit disgust (see description of film clips below). Disgust was chosen for the ease with which it can be elicited using films (Gross & Levenson, 1995). After each film clip participants were asked to watch a second fixation point on the television screen for another minute. They then rated the same 13 emotions as before, and rated how well they believed they followed the regulation instructions.

At the end of the day, participants were given an actigraphy wristwatch and sleep diary (described below) for use in the sleep phase of the study (see below), which was completed over the subsequent seven days, as well as a stamped and addressed envelope to return the research materials to the laboratory.

Apparatus and stimuli

Films. Five brief film clips from movies or television shows were used to elicit emotion in the reactivity trials. A 105-second black and white film clip from the television show "I Love Lucy" in which two women wrap chocolates was used to elicit amusement. An 86-second color film clip from the movie "The Champ" in which a boy cries after his father dies was used to elicit sadness. An 89-second color film clip from the television show "Fear Factor" in which a man eats cow intestine was used to elicit disgust. A 75-second color film clip from the television show "Red Shoes Diary" in which a man and a woman make love was used to elicit sexual arousal. A 59-second black and white film clip from the movie "American History X" in which a man is murdered was used to elicit distress. All five film clips were shown with their accompanying sound tracks.

Two brief film clips, one from a movie and one from a television show, were used to elicit disgust in the emotion regulation trials. A 83-second color film clip from the television show “Fear Factor” in which a woman eats balls of blood from a plate of worms was used in the suppression trial. A 93-second color film clip from the movie “Pink Flamingoes” in which a person eats dog feces was used in the amplification trial. These film clips were shown with their accompanying sound tracks.

Emotional behavior. Two cameras were concealed behind darkened mirrors in bookcases, and were controlled remotely. One camera recorded participants’ face and upper body throughout the laboratory session; the other recorded what the patient was shown on the video monitor. These images were combined into a single picture-in-picture image using a video special-effects generator. A room microphone and a lavalier microphone attached to the participant’s shirt recorded audio. The picture-in-picture image and the audio were simultaneously recorded to two DVDs and to a digital file.

Peripheral physiology. Physiological arousal was measured continuously with a 16-channel Biopac device connected to a computer. Measurements recorded included (a) inter-beat interval: electrodes with conductive paste were placed on opposite sides of the participant’s chest to assess heart rate. Inter-beat interval was calculated as the interval between successive R waves; (b) finger pulse amplitude: a photoplethysmograph recorded the amplitude of blood volume in the finger, using a photocell taped to the third finger of the participant’s nondominant hand; (c) finger pulse transmission time: the time interval in milliseconds was measured between the R wave of the electrocardiogram (EKG) and the upstroke of the peripheral pulse at the finger site, recorded from the distal phalanx of the ring finger of the nondominant hand with the photoplethysmograph; (d) ear pulse transmission time: a photoplethysmograph attached to the participant’s right earlobe recorded the volume of blood in the ear. Transmission time was measured between the R wave of the EKG and the upstroke of pulse at the ear; (e) skin conductance level: a constant-voltage device was used to pass a small voltage between electrodes attached to the first and third fingers of the participant’s nondominant hand; (f) general bodily activity: an electromechanical transducer attached to a platform under the participant’s chair generated an electrical signal proportional to the amount of movement in any direction. These measures were chosen to record a range of physiological activation: cardiac, electrodermal, and somatic. Pre-ejection period, respiratory sinus arrhythmia, systolic and diastolic blood pressure, and respiration were also measured, but were not used in the current analyses.

Sleep quality. Sleep quality was measured with an actigraphy wristwatch, or “actigraph,” which participants wore on their non-dominant arm. Actigraphs contain an accelerometer to measure how much the participants move the arm and a light sensor to measure the level of ambient light. Using the movement and ambient light data, the actigraphs provided several indicators of sleep quality including sleep efficiency, wake after sleep onset, and total sleep time. Actigraphy has been shown to be a valid measure of sleep quality across the lifespan. One study found no significant difference between actigraphy and polysomnography in measuring sleep efficiency, total sleep time, or wake after sleep onset in older adults (Lichstein et al., 2006). Another study comparing actigraphy to polysomnography in older adults found significant agreement for total sleep time, marginally significant agreement for wake after sleep onset, and acceptable accuracy for sleep efficiency above sleep efficiency levels of 73% (Taibi, Landis & Vitiello, 2013). Actigraphy has been noted to underestimate wake after sleep onset (de Souza et al., 2003), resulting in measurement that falls short of polysomnography, but it remains a useful objective tool for easily and inexpensively measuring sleep quality in the home.

Measures

Sleep diary. Participants completed a daily sleep diary including (a) whether they took any medications to help them sleep and, if so, which medications, (b) the time of day they tried to sleep, (c) the time of day they fell asleep, (d) how long they were awake between falling asleep and their final awakening in the morning, and (e) the time of day they woke up. They completed these diaries each evening before bed and each morning when they woke up for the seven days that they wore the actigraphs.

Data Reduction

Physiology. Software written by Dr. Robert Levenson was used to compute second-by-second averages for six physiological channels (inter-beat interval, finger pulse amplitude, finger pulse transmission time, ear pulse transmission time, skin conductance level, and general bodily activity), which were averaged to indicate physiological arousal for each channel within each baseline and film clip period. The values for the reactivity (amusement, sadness, disgust, sexual arousal, and distress) and regulation (suppression and amplification) trials were normalized and then averaged across physiological channels to create a composite baseline physiological arousal value and a composite film clip physiological arousal value for each trial. The values for interbeat interval, finger pulse amplitude, finger pulse transmission time, and ear pulse transmission time were multiplied by -1 before creating the composite so that higher values indicated greater arousal. Composite physiological reactivity for each trial was computed as the residual of the composite film clip physiological arousal regressed on the composite baseline physiological arousal; composite physiological reactivity for each regulation trial was computed as the residual of the composite regulation physiological arousal regressed on the composite baseline physiological arousal. This approach allowed us to reduce the number of statistical analyses conducted and thus help control for type 1 error (Eckart, Sturm, Miller, & Levenson, 2012). To ensure that this composite variable did not obscure important differences that might occur at the level of individual measures, a series of exploratory analyses were planned to test the association between reactivity measured with each physiological channel and sleep quality for each trial that was significantly associated with sleep quality. For these exploratory analyses, physiological reactivity for each physiological measure was computed by averaging second by second averages for the baseline physiological arousal and film clip physiological arousal, and residualizing the film clip physiological arousal on the baseline average for that measure. The physiological reactivity values for interbeat interval, finger pulse amplitude, finger pulse transmission time, and ear pulse transmission time were multiplied by -1 so that higher values indicated greater arousal.

Emotional behavior. Trained coders, blinded to the content of each film clip, rated participants' emotional behavior during a pre-selected 30-second "hot spot" in each reactivity and regulation film clip (the most emotionally intense portion of the film as rated by a panel of judges), using the Emotional Expressive Behavior System (Gross & Levenson, 1993). This system codes for two positive emotions (happiness/amusement, interest), one neutral emotion (interest), and seven negative emotions (anger, contempt, confusion, disgust, fear, embarrassment, and sadness). Each emotion was coded on a 0-3 intensity scale. Inter-rater reliability among coders was high ($\alpha = .91$). For each film, all ten emotion behaviors were averaged together to create a composite emotion behavior score. To ensure that this composite variable did not obscure important differences that might occur at the level of individual measures, a series of exploratory analyses were planned with each code (happiness/amusement,

interest, anger, contempt, confusion, disgust, fear, embarrassment, sadness, and surprise) for any trial in which composite emotion behavior was significantly associated with sleep quality.

Suppression effectiveness and amplification effectiveness were calculated in order to control for caregivers' success in regulating their emotion when analyzing the association between physiological reactivity to the regulation tasks and sleep quality. Suppression effectiveness was computed for each caregiver as the residual of emotional behavior expressed during the suppression task regressed on emotional behavior expressed during the disgust reactivity trial. Similarly, amplification effectiveness was computed for each caregiver as the residual of emotion behavior expressed during the amplification task regressed on emotion behavior expressed during the disgust reactivity trial.

Sleep quality. Actigraphy-measured sleep quality was computed using actigraphy data. Philips Actiware software (version 6.0.5) was used to reduce the actigraphy data and to compute minute-by-minute averages of wrist movement and ambient light. Rest intervals were computed using actigraphy, ambient light, and daily sleep diaries. The start of each rest interval was set at the reduction in ambient light closest to the time the caregiver reported attempting to sleep; the end of each rest interval was set at the increase in actigraphy closest to the time the caregiver reported waking up. Actigraph sensitivity was set to the medium level. Rest intervals and sleep actigraphy were used to compute sleep efficiency (i.e., the percentage of time in bed actually spent sleeping), wake after sleep onset (i.e., the number of minutes awake between falling asleep in the evening and final awakening in the morning), and total sleep time (i.e., the number of minutes asleep during the night). Actigraphy-measured sleep efficiency, total sleep time, and wake after sleep onset were each averaged over the course of the seven days to compute an average score for each of the three measures. Across the seven days, Chronbach's alpha for actigraphy-measured sleep efficiency was .83, for actigraphy-measured wake after sleep onset was .81, and for actigraphy-measured total sleep time was .84.

Sleep diary-reported sleep efficiency and sleep diary-reported total sleep time were computed from sleep diary data, using participants' daily self-reported time they tried to sleep, how long it took them to fall asleep, how long they were awake between falling asleep and their final awakening, and what time their final awakening occurred each day. Participants reported wake after sleep onset directly in the sleep diaries. Sleep diary-reported sleep efficiency, total sleep time, and wake after sleep onset were each averaged over the course of the seven days to compute an average score for each of the three sleep measures. Across the seven days, Chronbach's alpha for sleep diary-reported sleep efficiency was .87, for sleep diary-reported wake after sleep onset was .65, and for sleep diary-reported total sleep time was .66.

Cronbach's alpha for the six sleep variables (actigraphy-measured sleep efficiency, total sleep time, and wake after sleep onset, and sleep diary-reported sleep efficiency, total sleep time, and wake after sleep onset) was computed in order to determine whether the variables could be composited to a single sleep quality variable. Cronbach's alpha was .68. By dropping the variable least associated with the others, sleep diary-reported sleep efficiency, Cronbach's alpha increased to .71; this value indicated good reliability across variables. The remaining five variables (actigraphy-measured sleep efficiency, wake after sleep onset, and total sleep time, and sleep diary-reported wake after sleep onset and total sleep time) were used to compute a composite sleep quality variable: the standardized actigraphy-measured and sleep diary-reported wake after sleep onset variables were multiplied by -1 so that higher values indicated better sleep quality for all five variables, and then the five standardized variables were averaged to compute composite sleep quality. Caregivers were excluded from analyses if they had fewer than three of

the five sleep variables necessary to compute the sleep quality variable, or if they had completed fewer than four nights of sleep actigraphy and sleep diary.

Results

Preliminary Analysis

Missing data occurred for some participants. Three caregivers did not respond to questions regarding the use of sleep medications during the week of sleep data collection. Four caregivers only partially completed sleep diaries, resulting in four caregivers missing data for sleep diary-reported total sleep time and one caregiver missing data for sleep diary-reported wake after sleep onset. The video recordings of emotion behavior were missing due to procedural errors for eight caregivers on at least one reactivity trial, for five caregivers on the suppression trial, and for ten caregivers on the amplification trial. All analyses were completed using the maximum number of available cases.

Descriptive statistics of caregivers' self-reported emotions following each film and regulation task were calculated, and are presented in Table 2. Caregivers' self-report indicated that they most strongly felt "amused" following the amusement film, "sad" following the sadness film, and "disgusted" following the disgust film. Caregivers' self-report indicated that they felt multiple emotions at similar intensity following the sexual arousal film and distress film. They reported feeling "calm," "affectionate," and "sexually aroused" following the sexual arousal film, and "disgusted," "sad," and "angry" following the distress film. Their self-report indicated that they most strongly felt "disgusted" following the suppression and amplification tasks.

Descriptive statistics of caregivers' sleep quality were calculated, and are presented in Table 3. Caregivers completed an average of 6.9 nights of sleep quality data collection ($SD = .6$).

A series of two-sample t-tests were conducted to compare sleep quality variables in this sample to those in published samples, using the published means, standard deviations, and sample sizes. Compared to published actigraphy-measured and sleep diary-reported sleep quality in healthy older adults (Landry, Best, & Liu-Ambrose, 2015), the present sample had better actigraphy-measured sleep efficiency ($t(116) = 2.68, p = .009$), similar actigraphy-measured total sleep time ($t(116) = -.65, p = .51$), worse actigraphy-measured wake after sleep onset ($t(116) = 5.84, p < .001$), and similar sleep diary-reported total sleep time ($t(116) = 1.24, p = .22$). Because Landry and colleagues (2015) did not publish sleep diary-reported wake after sleep onset data, a different source was used to compare that value in the present sample to a published sample of healthy older adults (Wohlgemuth, Edinger, & Fins, 1999); the current sample had better (lower) sleep diary-reported wake after sleep onset compared to the previously published sample ($t(64) = -4.69, p < .001$).

Demographic covariates that might affect the results were considered. Composite sleep quality was not significantly associated with caregiver age, gender, or use of any sleep medications during the week of sleep data collection. (Correlation coefficients presented in Table 4.) Thus, caregiver age, gender, and use of sleep medications during the week of data collection were not included as covariates in the analyses. Also, because the use of sleep medications during the week of data collection was not associated with sleep quality, the three caregivers who did not indicate whether they took any sleep medications during the week were included in the analyses.

Physiological Reactivity and Sleep Quality

Main analysis. To test the hypothesis that greater physiological reactivity to emotion-eliciting films would be associated with worse sleep quality during the following week, I

conducted an initial regression in which the predictors were composite physiological reactivity to each of the five emotion reactivity films and the criterion variable was composite sleep quality. Results revealed that greater physiological reactivity to the sexual arousal film, and less physiological reactivity to the distress film, were associated with better sleep quality (sexual arousal film: $\beta = .33, p = .04$; distress film: $\beta = -.36, p = .04$). Physiological reactivity to the other films was not associated with sleep quality (amusement: $\beta = -.04, p = .81$; sadness: $\beta = .05, p = .80$; disgust: $\beta = -.12, p = .47$). Thus, my hypothesis was only partially supported; greater physiological reactivity to the distress film was associated with worse sleep quality, though greater physiological reactivity to the sexual arousal film was associated with better sleep quality and physiological reactivity to the other films were not associated with sleep quality at all.

Exploratory analyses. Exploratory analyses were conducted to quantify the variance in sleep quality explained by the significant predictors from the main analysis, to examine the contribution of individual measures of physiological reactivity to the significant associations found in the main analysis, and to test for reliability of the significant associations found in the main analysis across diagnostic group and caregiver sex. Because composite physiological reactivity to the sexual arousal and distress films were the only variables that significantly predicted composite sleep quality, exploratory analyses focused on physiological reactivity to these films.

Variance in sleep quality explained by significant predictors from main analysis. To measure the variance in sleep quality explained by the significant predictors from the main analysis, a regression was performed in which the predictors were composite physiological reactivity to the sexual arousal and distress films and the criterion variable was composite sleep quality. Results indicated that both greater physiological reactivity to the sexual arousal film and less physiological reactivity to the distress film were associated with better sleep quality (sexual arousal film: $\beta = .34, p = .03$; distress film: $\beta = -.35, p = .02$). Together, physiological reactivity to the sexual arousal film and the distress film accounted for 20% of the variance in composite sleep quality ($R^2 = .20, R^2_{\text{adj}} = .16, F(2,37) = 4.60, p = .02$).

Contribution of individual physiological channels toward explaining sleep quality. Because the predictors in the main analysis were composites, exploratory analyses were performed to examine the association between physiological reactivity and sleep quality at the level of the individual physiological channels for each of the two films.

First, a regression was performed in which the predictors were the six individual measures of physiological reactivity to the sexual arousal film (the residuals of the film clip physiological arousal regressed on the baseline physiological arousal, with physiological reactivity values for interbeat interval, finger pulse amplitude, finger pulse time, and ear pulse time multiplied by -1 so that higher values indicated greater reactivity). The criterion variable in this regression was composite sleep quality. None of the individual measures of physiological reactivity to the sexual arousal film was significantly associated with sleep quality (interbeat interval (multiplied by -1): $\beta = .17, p = .33$; finger pulse amplitude (multiplied by -1): $\beta = .03, p = .89$; finger pulse time (multiplied by -1): $\beta = .02, p = .93$; ear pulse time (multiplied by -1): $\beta = .07, p = .72$; skin conductance level: $\beta = .24, p = .25$; somatic activity: $\beta = -.03, p = .88$).

A regression was then performed in which the predictors were the six individual measures of physiological reactivity to the distress film (the residuals of physiological arousal during the film clip regressed on the baseline physiological arousal, with physiological reactivity values for interbeat interval, finger pulse amplitude, finger pulse time, and ear pulse time multiplied by -1 so that higher values indicated greater reactivity). The criterion variable in this

regression was composite sleep quality. None of the measures of physiological reactivity to the distress film was significantly associated with sleep quality (interbeat interval (multiplied by -1): $\beta = -.17, p = .41$; finger pulse amplitude (multiplied by -1): $\beta = .20, p = .39$; finger pulse time (multiplied by -1): $\beta = -.20, p = .39$; ear pulse time (multiplied by -1): $\beta = .07, p = .68$; skin conductance level: $\beta = -.04, p = .80$; somatic activity: $\beta = -.11, p = .52$).

In summary, no individual measure of physiological reactivity to the sexual arousal film or the distress film was associated with sleep quality.

Reliability of association between physiological reactivity and sleep quality across patient neurodegenerative disease. To test the reliability of the association between physiological reactivity to the sexual arousal and distress films and sleep quality across patients' neurodegenerative disease, exploratory analyses were conducted separately for each of the largest diagnostic categories in the sample: frontotemporal dementia (n=13), Alzheimer's disease (n=9), and progressive supranuclear palsy (n=7).

In the first regression, I included only caregivers of patients with frontotemporal dementia. The predictors were composite physiological reactivity to the sexual arousal film and to the distress film, and the criterion variable was composite sleep quality. Neither predictor was significantly associated with sleep quality (sexual arousal: $\beta = -.07, p = .82$; distress: $\beta = -.23, p = .47$).

In the second regression, I included only caregivers of patients with Alzheimer's disease. The predictors were composite physiological reactivity to the sexual arousal film and to the distress film, and the criterion variable was composite sleep quality. Greater physiological reactivity to the sexual arousal film was marginally associated with better sleep quality ($\beta = .55, p = .10$); less physiological reactivity to the distress film was significantly associated with better sleep quality ($\beta = -.78, p = .03$).

In the third regression, I included only caregivers of patients with progressive supranuclear palsy. The predictors were composite physiological reactivity to the sexual arousal film and to the distress film, and the criterion variable was composite sleep quality. Greater physiological reactivity to the sexual arousal film was marginally associated with better sleep quality ($\beta = .82, p = .07$); greater physiological reactivity to the distress film was not associated with sleep quality ($\beta = -.33, p = .40$).

In summary, greater reactivity to the sexual arousal film was marginally associated with better sleep quality for caregivers of patients with Alzheimer's disease and progressive supranuclear palsy but not frontotemporal dementia; less reactivity to the distress film was significantly associated with better sleep quality for caregivers of patients with Alzheimer's disease, but not progressive supranuclear palsy or frontotemporal dementia. The direction of the effects was consistent for physiological reactivity to the sexual arousal film for caregivers of patients with Alzheimer's disease and progressive supranuclear palsy, and for physiological reactivity to the distress film for all three diagnoses.

Reliability of association between physiological reactivity and sleep quality across caregiver sex. In order to test the reliability of the association between physiological reactivity to the sexual arousal and distress films and sleep quality across caregivers' sex, additional exploratory analyses were conducted separately for female caregivers and male caregivers.

In the first regression, I included only female caregivers. The predictors were composite physiological reactivity to the sexual arousal film and to the distress film, and the criterion variable was composite sleep quality. Neither predictor was significantly associated with sleep quality (sexual arousal: $\beta = .33, p = .12$; distress: $\beta = -.31, p = .14$).

In the second regression, I included only male caregivers. The predictors were composite physiological reactivity to the sexual arousal film and to the distress film, and the criterion variable was composite sleep quality. Greater physiological reactivity to the sexual arousal film was marginally associated with better sleep quality ($\beta = .49, p = .07$). Physiological reactivity to the distress film was not significantly associated with sleep quality ($\beta = -.43, p = .12$).

In summary, greater physiological reactivity to the sexual arousal film was marginally associated with better sleep quality for male caregivers. Notably, the strength and directions of the effects were reasonably consistent across sex for physiological reactivity to the sexual arousal film and for physiological reactivity to the distress film.

Summary of physiological reactivity and sleep quality findings. In summary, greater physiological reactivity to the sexual arousal film, and lower physiological arousal to the distress film, were associated with better sleep quality. No individual physiological measure of reactivity to either film was associated with sleep quality. The association between physiological reactivity to the sexual arousal film was marginally associated with sleep quality for caregivers of patients with Alzheimer's disease and progressive supranuclear palsy, but not frontotemporal dementia. The association between physiological reactivity to the distress film and sleep quality was significant for caregivers of patients with Alzheimer's disease, but not frontotemporal dementia or progressive supranuclear palsy. The association between physiological reactivity to the sexual arousal film was marginally associated with sleep quality for male caregivers, though not for female caregivers. The association between physiological reactivity to the distress film was not significantly associated with sleep quality for either sex.

Expressive Reactivity and Sleep Quality

Main analysis. To test the hypothesis that greater expressive reactivity to emotion-eliciting films would be associated with worse sleep quality during the following week, I conducted an initial regression in which the predictors were composite expressive reactivity to each of the five emotion reactivity films and the criterion variable was composite sleep quality. Results revealed that expressive reactivity was not significantly associated with sleep quality (amusement: $\beta = -.05, p = .84$; sadness: $\beta = -.13, p = .53$; disgust: $\beta = .05, p = .84$; sexual arousal: $\beta = -.33, p = .13$; distress: $\beta = -.11, p = .58$).

Because behavioral data are often skewed (Holsclaw, Hallgren, Steyvers, Smyth, & Atkins, 2015), I tested the assumption of normality of the regression residuals. The Shapiro-Wilk test found no deviation from normality in the regression residuals ($W = .97, p = .46$). Thus, the normality of regression residual assumption was deemed not to be violated in the regression of sleep quality on expressive reactivity, and using transformations to improve normality of the variables was not necessary.

Because the hypothesis was not supported, no follow-up exploratory analyses were performed.

Physiological Reactivity during Emotion Suppression and Sleep Quality

Main analysis. To test the hypothesis that greater physiological reactivity to an emotion suppression task would be associated with worse sleep quality, I conducted an initial regression in which the predictors were composite physiological reactivity to the suppression task and suppression effectiveness (that is, the residual of emotional behavior expressed during the suppression task regressed on emotional behavior expressed during the disgust trial), and the criterion variable was composite sleep quality. Suppression effectiveness was included as a predictor in order to control for participants' success in suppressing their emotion behavior. Results found that neither physiological reactivity to the suppression task nor suppressive

effectiveness were associated with sleep quality (physiological reactivity to the suppression task: $\beta = -.03, p = .85$; suppression effectiveness: $\beta = .01, p = .95$).

Thus, the hypothesis was not supported and no follow-up exploratory analyses were performed.

Physiological Reactivity during Emotion Amplification and Sleep Quality

Main analysis. To explore whether physiological reactivity to an emotion amplification task would be associated with sleep quality, I conducted an initial regression in which the predictors were composite physiological reactivity to the amplification task and amplification effectiveness (that is, the residual of emotional behavior expressed during the amplification task regressed on emotional behavior expressed during the disgust trial), and the criterion variable was composite sleep quality. Amplification effectiveness was included as a predictor in order to control for participants' success in amplifying their emotion behavior. Neither physiological reactivity to the amplification task nor amplification effectiveness were associated with sleep quality (physiological reactivity to the amplification task: $\beta = -.01, p = .97$; amplification effectiveness: $\beta = -.13, p = .52$). Thus, the hypothesis was not supported and no follow-up exploratory analyses were performed.

Discussion

The present study examined the association between emotional reactivity and regulation measured in the laboratory and sleep quality measured over a one week period in the home in a sample of caregivers of patients with neurodegenerative disease. To achieve this, physiological and expressive reactivity to five brief films, and physiological reactivity and regulation effectiveness to two regulation tasks, were considered. Sleep quality was measured using both prospective self-reported sleep quality and actigraphy-measured sleep quality. Compared to previously published samples, caregivers in the current study had better sleep quality for some measures and worse sleep quality for one measure. A sleep quality composite comprised of both actigraphy-measured and sleep diary-reported indicators of sleep quality was computed. The major finding was that greater physiological reactivity to a sexual arousal film, and less physiological reactivity to a distress film, were associated with better sleep quality. The finding for physiological reactivity to the sexual arousal film was reliable across caregivers for two of the three most common neurodegenerative diseases in the sample (found for Alzheimer's disease and progressive supranuclear palsy, not found for frontotemporal dementia); the finding for physiological reactivity to the distress film was reliable across caregivers for all three of the most common neurodegenerative diseases in the sample. Both findings were reliable across caregiver sex.

No significant associations with sleep quality were found for expressive reactivity, physiological reactivity to an emotion suppression task, or physiological reactivity to an emotion amplification task.

Caregiver Sleep Quality as Compared to Published Samples

Individual measures of caregivers' sleep quality were compared to those of previously published samples of non-caregiver older adults. Caregivers in the present study had better actigraphy-measured sleep quality and sleep-diary reported wake after sleep onset, and worse actigraphy-measured wake after sleep onset. No differences were found for actigraphy-measured total sleep time or sleep diary-reported total sleep time. Interestingly, no clear pattern with regard to sleep quality measures emerged from these results; caregivers' actigraphy appeared inconsistent, yielding one better and one worse result for sleep quality, and even within the construct of wake after sleep onset, sleep diary-measurement showed better sleep quality in the

caregivers whereas actigraphy-measurement showed worse sleep quality. These results are consistent with the findings for caregivers' sleep quality in the literature, with caregivers sometimes sometimes similar to and sometimes worse than non-caregiver older adults (Castro et al., 2009; McKibbin et al., 2005; Rowe et al., 2008). The similarity in sleep quality to non-caregiver older adults may be due to sampling bias. Most of the caregivers in the current sample were caregivers for patients relatively early in the course of their disease, and most were also living in the greater San Francisco bay area, where they may have access to greater resources than caregivers in other locations. Caregivers who choose to participate in the larger research study at the BPL may also be less burdened than other caregivers. Any of these factors might influence in a sample of caregivers with lower stress than other caregivers, and thus without severe or consistent problems with sleep quality relative to non-caregiver older adults.

Greater Physiological Reactivity to a Sexual Arousal Film and Better Sleep Quality

Contrary to my hypothesis, greater physiological reactivity to the sexual arousal film was associated with *better* sleep quality. Although this association was unanticipated, the finding fits with longstanding cultural associations between sex and sleep: intercourse is referred to as “sleeping with” someone, and both activities are most often thought of as occurring in bed. These cultural associations are at least partly biological: in men, sexual climax is associated with a release of prolactin, which causes feelings of sleepiness, and in both men and women, sexual climax releases estrogens and progesterins, which improve sleep quality (Paul, Turek, & Kryger, 2008).

The association between greater physiological reactivity to the sexual arousal film and better sleep quality may be attributable to the film mostly eliciting calm, pleasant emotions. Previous research has reliably linked self-report of more frequent positive emotion and better sleep quality (Kahn et al., 2013). In the present study, the sexual arousal film elicited emotions beyond mere sexual arousal; caregivers also reported feeling “affectionate” and “calm” during the film. These low-arousal positive emotions may have driven the link between physiological reactivity to the sexual arousal film and sleep quality. If this were the case, we might expect to see an association between expressive reactivity to the sexual arousal film and sleep quality as well, yet no such association was found. Other factors, described below, may explain why expressive reactivity to the sexual arousal film was not found to be associated with sleep quality. If the finding was due to the positivity of the emotions the film elicited regardless of *which* positive emotion, we might also expect to see an association between physiological reactivity to the amusement film and sleep quality. The fact that no such association was found may speak to the diversity of positive emotions (Shiota et al., 2014), and the important distinctions between amusement on one hand, and the affection, calmness, and sexual arousal that caregivers reported in response to the sexual arousal film on the other. Different positive emotions may be associated with sleep to different degrees; being more strongly reactive to stimuli that elicit affection and calmness may contribute to better sleep than does being more strongly reactive to the style of slapstick humor displayed in the amusement film.

Greater Physiological Reactivity to a Distress Film and Worse Sleep Quality

The hypothesis that greater physiological reactivity to emotion-eliciting films would be associated with worse sleep quality was supported for the distress film alone; no such association was found for the amusement, sadness, or disgust films, and the association between physiological reactivity to the sexual arousal film and sleep quality was in the opposite direction. Why was the hypothesized association found only for the distress film?

The emotions elicited by the distress film may be more salient to caregivers' daily lives than the emotions elicited by the amusement, sadness, or disgust films. After watching the film, caregivers reported feeling "disgusted," "sad," and "angry." Disgust and anger correspond to feelings of moral outrage, and may be relevant to the feelings that some caregivers anecdotally report feeling in response to the injustice of their spouse's diagnosis. The sadness that caregivers reported in response to the film may be salient to caregivers' sadness in their daily lives for the loss of their partner's health and ability to function. The emotional experience of anticipating and observing harm and death in the film may be relevant to caregivers' emotional experience anticipating and observing the progression of the neurodegenerative disease in their partner. The complex combination of negative emotions that the film elicits may occur more often in caregivers' daily lives than the individually-elicited experiences of amusement, sadness, or disgust. If these emotions occur fairly often in caregivers lives, and greater physiological arousal disrupts sleep regardless of the source, then caregivers who show greater physiological reactivity to the distress film (ie, those who are more sensitive to the negative emotions that the film elicits) would experience worse sleep quality, as was shown.

Association Between Physiological Reactivity and Sleep Quality, Across Diagnosis and Sex

Exploratory analyses indicated that physiological reactivity to the sexual arousal film was marginally associated with sleep quality for caregivers of patients with Alzheimer's disease and supranuclear palsy but not frontotemporal dementia; physiological reactivity to the distress film was significantly associated with sleep quality for caregivers of patients with Alzheimer's disease, but not progressive supranuclear palsy or frontotemporal dementia. Considering the small sample sizes used in these analyses, the significance levels are less meaningful than the size and direction of the effects. The effects were reasonably consistent for physiological reactivity to the sexual arousal film for caregivers of patients with Alzheimer's disease and progressive supranuclear palsy, and for physiological reactivity to the distress film for all three diagnoses. These findings should be interpreted with caution, as the statistical power is low. Findings may suggest that caregivers of patients with frontotemporal dementia differ from other caregivers in the association between physiological reactivity to sexual arousal stimuli and sleep quality. Caregivers of patients with frontotemporal dementia report greater burden and lower relationship satisfaction than caregivers of patients with Alzheimer's disease (Ascher et al., 2010; Riedijk et al., 2006); these factors may influence the association between physiological reactivity to sexual arousal and sleep quality.

The reliability of the findings for physiological reactivity to a sexual arousal film across caregivers of patients with Alzheimer's disease and progressive supranuclear palsy, and physiological reactivity to a distress film across caregivers of patients with all three diagnoses, suggest that the findings may generalize to caregivers of patients with other neurodegenerative diseases.

Exploratory analyses also indicated that physiological reactivity to the sexual arousal and distress films were reliably associated with sleep quality for both male and female caregivers. Although these results were not statistically significant, the directions and strength of the findings were consistent across sex. These results suggest that the link between physiological reactivity and sleep quality may be robust for caregivers of either sex.

Caregivers' Expressive Reactivity and Sleep Quality

Caregivers' expressive reactivity was not significantly associated with sleep quality in the present study. This may suggest that, unlike physiological reactivity, behavioral expression of emotion in response to emotional film stimuli is not related to sleep quality. Alternately, the

current study may have simply lacked sufficient power to detect any relatively-small association between expressive reactivity and sleep quality. Though they were not statistically significant, the associations between expressive reactivity and sleep quality in the current study were largely consistent with each other (that is, in the same direction): less expressive reactivity to all but one film was associated with better sleep quality (amusement, sadness, sexual arousal, and distress; not disgust), and the strength of the association for the exception was very small, suggesting that it may have differed from the other associations due to sampling error and not due to a meaningful difference compared to expressive reactivity to the other films. This interpretation may appear to contradict the main findings of this study, as less expressive reactivity to the sexual arousal film was the strongest predictor of better sleep quality among the expressive reactivity variables, whereas greater physiological reactivity to the sexual arousal film was significantly associated with better sleep quality. The difference in findings for expressive as opposed to physiological reactivity to the sexual arousal film might be reasonably explained by other factors, however. For example, caregivers may have been reluctant to display positive emotion in response to sexually explicit stimuli, the emotions elicited by the films may not be associated with strong expressive behaviors (e.g., feeling “calm” or “affectionate” while watching the sexual arousal film), or (as discussed below) the EEB coding system may not have accurately captured behaviors associated with sexual arousal.

The EEB coding system used in the present study may neglect the expressive behaviors most associated with sleep quality. Physiological reactivity to only two films was associated with sleep quality: a sexual arousal film and a distress film. EEB may not have captured the emotions elicited by these films. Although some expressive behaviors such as licking lips are reliably associated with sexual arousal (Gonzaga, Turner, Keltner, Campos, & Altemus, 2006), EEB does not capture these behaviors. Had expressive reactivity to the sexual arousal film been coded using a more appropriate coding system, perhaps it would have been associated with sleep quality just as physiological reactivity was. A similar problem may have occurred for the distress film. Although the film elicited some emotions that were explicitly coded-for, including anger, disgust, and sadness, the film may have elicited emotion behaviors that were not captured. The distress film shows a man being murdered by another man, and although the violence occurs off-screen, it is strongly suggested. Caregivers watching this film may have, for example, winced in sympathy or distress, but the EEB coding system does not include “wincing” behavior in any of its emotion codes. A different coding system may have better captured emotional behaviors elicited by the sexual arousal film and the distress film that are associated with sleep quality.

Caregivers’ Emotion Regulation and Sleep Quality

The present findings indicated that caregivers’ emotion suppression and emotion amplification were not associated with their sleep quality. On the face of it, these results suggest that the physiological burden of emotion suppression and emotion amplification do not impair sleep.

Other forms of emotion regulation may still be associated with sleep quality. The present study only considered two types of emotion regulation: suppression and amplification. Several other types of emotion regulation exist and may be more relevant, more burdensome, or both, for caregivers. Reappraisal, for example, may be associated with sleep quality in a way that suppression and amplification seem not to be. Reappraisal is a more effective emotion regulation strategy than is suppression, and also is associated with lower physiological arousal (Gross, 2002). Perhaps caregivers’ greater ability to reappraise emotion is associated with lower stress and better sleep quality.

Alternately, perhaps no significant association was found because of the artificiality of the laboratory setting. Any instructed regulation may be too far removed from caregivers' daily lives in their homes to be relevant to caregivers' sleep quality; a measure with more naturalistic validity may be necessary. Similarly, in the present study caregivers were asked to suppress and amplify expressive behavior in response to disgusting stimuli. Suppression and amplification of disgust may not be salient to caregivers' experiences; suppression of anger, frustration, or anxiety, and amplification of positive emotion, may be more salient. Suppressing or amplifying emotion in an interpersonal context, as they might have to at home with the patient, may also be more representative of their daily life and may be more relevant to their sleep quality.

Or, emotion suppression and emotion amplification simply may not be relevant to caregivers' daily lives. Caregivers may not engage in emotion suppression and amplification frequently. If this is the case, then emotion suppression and amplification would not be found to have any association with sleep quality, even if these regulation strategies do affect sleep in people who use them frequently.

Strengths and Limitations

The present study has several strengths and limitations. One strength was that the study examined sleep in an under-studied population at high risk for sleep disruption. Spousal caregivers of patients with neurodegeneration report significant disruptions to their sleep quality, but few studies have examined sleep quality in this population, let alone examined emotional reactivity or emotion regulation as it relates to sleep quality.

An additional strength was the inclusion of caregivers of patients with a range of neurodegenerative diseases. Different neurodegenerative diseases cause different levels of caregiver burden. Caregivers of patients with frontotemporal dementia, for example, report higher levels of behavioral disturbances in the patients and greater caregiver burden than do caregivers of patients with Alzheimer's disease. By including caregivers of patients with a range of neurodegenerative diseases including frontotemporal dementia, Alzheimer's disease, progressive supranuclear palsy, Parkinson's disease, and several others, this study suggests that the associations found for emotion reactivity and sleep quality are found for caregivers of patients with neurodegenerative disease broadly, and not just true of caregivers of patients with a particular neurodegenerative disease.

Another strength was the use of multiple objective measures of emotion reactivity and emotion regulation. Physiological and expressive measures are reliable ways to capture emotion, and capture different facets of emotion: internal (physiological arousal) and external (expressive behavior). Additionally, compared to self-reported emotion, both sets of measures are less easily biased by participants' desire to appear a particular way (e.g., more empathic, more stoic, or in the case of regulation tasks, more effective than they may actually be).

A final strength is the use of both sleep diary-reported and actigraphy-measured sleep quality. Both measures have significant strengths over subjective and retrospective self-reported sleep quality, and both have their own strengths as well. Actigraphy, for example, has been found to correspond more closely to polysomnography, the gold-standard in sleep measurement, than do sleep diaries (Vallieres & Morin, 2003), whereas sleep diaries measure wake periods more accurately than actigraphy (Kawada, 2008). Using both sleep diary-reported and actigraphy-reported sleep quality in the present study allowed for a balance between the strengths and weaknesses of sleep diary-reported and actigraphy-measured sleep quality data, while maintaining their strengths above subjective and retrospective self-report of sleep quality.

The present study had several limitations as well. For example, it did not have a control group. Thus, we cannot infer whether the findings are specific to caregivers of patients with neurodegenerative disease, or whether they generalize to a population of non-caregiving couples of a similar age. The sample size of 40 caregivers was relatively small, and the statistical power of the analyses was not high enough to significantly detect small effects. As described above, the EEB coding system used in the present study may not have been sensitive to some of the likely emotional behaviors elicited by the sexual arousal and distress films. Additionally, the regulation tasks used in the present study may not have been salient to caregivers' daily lives; inclusion of a reappraisal trial, or use of stimuli that primarily elicited emotions other than disgust, may have allowed for better understanding of how caregivers' emotion regulation relates to sleep quality.

Directions for Future Research

This study raises several questions that might be addressed in future research. First, do the findings of the present study also occur in non-caregivers? Replicating the study in a sample of healthy adults would allow us to understand whether the associations between physiological reactivity to distress and sexual arousal films and sleep quality are specific to caregivers, or whether it occurs for others as well.

A second question that might be addressed in future research is, what drives the association between greater physiological reactivity in response to the sexual arousal film and better sleep quality? A future study could further explore how reactivity to different positive emotions, with different arousal levels and related to different degrees of interpersonal connection (e.g., contentment, excitement, nurturant love, sexual desire), might predict sleep quality.

A third question is whether emotional reactivity and sleep quality jointly predict caregivers' long-term health outcomes (e.g., neurodegenerative disease, cardiovascular illness, depression). Better sleep quality predicts a number of positive health outcomes (Irwin, 2015). Following caregivers longitudinally, and tracking changes in their health over time, would allow for analyzing the potential of emotional reactivity and sleep to predict health. Other research has found that emotion behaviors during a disagreement with one's spouse predicts health problems years later; specifically, greater expressions of anger predict cardiovascular problems, and more stonewalling behavior (i.e., withdrawing from conversation, not acknowledging one's spouse) predicts musculoskeletal problems (Haase, Holley, Bloch, Verstaen, & Levenson, 2016). The emotion behaviors observed during the disagreement are assumed to occur habitually and frequently, and the stress of many small incidents of anger or of stonewalling are hypothesized to collectively result in slowly-developing physical damage to the body. Similarly, sleep might mediate relations between emotional reactivity and health over the course of years. Collecting data on caregivers' physical and psychological health periodically for years after measuring emotional reactivity and sleep quality would allow for analyses testing this possibility.

A final question is, to what degree does emotional reactivity in the home environment affect sleep quality? In the present study, caregivers' emotional reactivity was measured in the laboratory, suggesting that some aspects of emotional reactivity in the laboratory predicted sleep quality at home. Previous research shows that mood inductions immediately before bed affect the time it takes to fall asleep (Talbot, McGlinchey, Kaplan, Dahl, & Harvey, 2010), but to date no one has studied how emotional *reactivity* before going to bed in the home environment affects sleep, let alone studied this topic in caregivers.

Clinical Implications

In terms of clinical implications, a future study could involve teaching caregivers effective tools for reducing their emotion reactivity to distressing stimuli, such as emotion reappraisal strategies (Gross, 2002), and measuring sleep quality after the training. And although an intervention aimed at increasing caregivers' reactivity to sexual arousal stimuli may be inappropriate, non-judgmental psychoeducation on sex in old age and in relationships where one partner has a neurodegenerative disease may help caregivers to be more comfortable with their sexuality, which may improve their sleep. Studies like these would allow the clinical implications of the present study to be more fully understood.

Conclusion

Few studies have examined the link between emotion and sleep quality in spousal caregivers of patients with neurodegenerative disease. To our knowledge, the present study is the first to examine objective laboratory measures of emotion reactivity or emotion regulation as they relate to sleep quality in this at-risk sample. The results indicate that greater physiological reactivity to a sexual arousal film, and less physiological reactivity to a distress film, are associated with better sleep quality. These results suggest future directions both for research and for clinical interventions that might help restore sleep in a population that suffers both from poor sleep quality and from a number of mental and physical health problems associated with poor sleep quality.

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Table 1. *Patients' diagnoses of neurodegenerative disease.*

<u>Diagnosis</u>	
Frontotemporal Dementia	13
Alzheimer's Disease	9
Progressive Supranuclear Palsy	7
Cortical Basal Syndrome	3
Parkinson's Disease	3
Primary Progressive Aphasia	3
Mild Cognitive Impairment	1
Mixed (Primary Cortical Atrophy and Cortical Basal Syndrome)	1
Total	40