IMPACT OF EXPERIMENTAL SLEEP EXTENSION ON ADOLESCENT SOCIAL EMOTION REGULATION

A Dissertation

Presented to

The Faculty of the Department

of Psychology

University of Houston

In Partial Fulfillment

Of the Requirements for the Degree of

Doctor of Philosophy

By

Katharine C. Reynolds

August, 2017

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ABSTRACT

Approximately 80% of adolescents do not receive adequate sleep. Sleep loss is particularly detrimental to emotional functioning, yet examination of the protective qualities of increased sleep are lacking. The current study sought to expand existing knowledge in this area by comparing teens assigned to either sleep extension (SE) or typical sleep (TS) conditions on multimodal measures of mood, emotional reactivity, and emotion regulation within a social context. A total of 30 adolescents were enrolled. Baseline measures of psychological symptoms, sleep problems/disorders, and mood were completed prior to 7 nights of at-home, typical sleep (Phase 1; baseline phase). Participants were then randomized to either SE (n = 20; required to sleep additional 30 minutes) or TS (n = 10; no sleep directions given) for 5 nights (Phase 2; experimental phase). A total of 10 participants randomized to SE were excluded due to non-compliance with sleep manipulation, resulting in a final sample of n=20 adolescents. Participants returned to the lab following Phase 2 for an assessment of emotional reactivity and emotion regulation via a computerized task (frustrating computer game) and two computerized social interactions (naturalistic and manipulated interactions) designed with specific emotional goals. Both subjective and objective measures of emotion were collected. Results indicated that participants in the SE group displayed greater (i.e., more appropriate) negative facial expression (large effect size) during the frustrating computer game. More effective emotion regulation was also detected in the SE group, demonstrated by an increase in subjective ratings of valence and arousal and objective language (word count) during a goal directed social interaction relative to a naturalistic interaction task (medium effect sizes), even after engaging in a frustrating computer game. These patterns were not observed in the TS group. Together, results suggest that an additional 30 minutes of sleep for 5 nights assisted adolescents in up-regulating positive affect in order to meet social interaction goals. These findings may have meaningful implications for adaptive peer functioning and reduced affective risk during the vulnerable socio-emotional period of adolescence. Although findings need to be replicated in larger samples, preliminary results suggest that an additional 30 minutes of sleep may improve emotion regulation skills in healthy adolescents.

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INTRODUCTION

Sleep is essential for sustaining life. This biological need is especially important for healthy child development, as sleep dominates the first few years of life (Anders, Sadeh, & Appareddy, 1995). Inadequate sleep, either due to sleep problems or limited sleep opportunity, is linked with various psychiatric disorders (Alfano, Beidel, Turner, & Lewin, 2006; Alfano, Ginsburg, & Kingery, 2007; Gregory, Eley, O'Connor, Rijsdijk, & Plomin, 2005; Gregory & O'Connor, 2002; Kamphuis, Meerlo, Koolhaas, & Lancel, 2012) yet many psychologically healthy children also experience sleep related problems. Between 20-30% of children 1-3 years of age and up to 43% of school aged children experience sleep problems (Kahn et al., 1989; Mindell, 1993; Sadeh & Gruber, 1998). In adolescence, around 10% of youth experience problems falling asleep (Morrison, McGee, & Stanton, 1992) and recent survey data indicate around 80% of adolescents do not get adequate amounts of sleep (i.e., less than the recommended 8-10 hours; Paruthi et al., 2016), particularly on weekdays (National Sleep Foudation [NSF] 2006). Adolescence also coincides with increased risk taking and sensation seeking behaviors, as well as increased psychiatric morbidity (Kessler et al., 2005). When combined with chronically inadequate amounts of sleep, adolescence represents a highly vulnerable period for the development of mental health problems.

The current study sought to better understand the relationship between sleep and emotional functioning during the high-risk period of adolescence. Previous experimental research in teenage samples have primarily utilized sleep deprivation/restriction paradigms to examine the impact of inadequate sleep on emotional outcomes (Baum et al., 2014; McMakin et al., 2016; Talbot, McGlinchey, Kaplan, Dahl, & Harvey, 2010). Although informative, the primary limitation of the sleep deprivation/restriction approach is that many adolescents are already sleep deprived prior to experimental sleep manipulation. Additionally, limited research has examined how to reverse emotional impairments caused by sleep loss. By comparison, this study utilized an experimental sleep extension (SE) paradigm to examine the specific protective role of sleep with regard to emotional functioning. Supported by the body of research reviewed below directly linking sleep to emotional functioning in adolescence, the current study examined the impact of SE on various aspects of emotion.

Sleep and Affective Risk in Adolescence

Youth experience a spike in physical and psychological changes with the onset of puberty. Adolescence is often considered a time of "storm and stress", classified by increased behaviors of rejecting authority (Steinberg & Silk, 2002), increased risk taking (Blum & Nelson-Mmari, 2004; Williams, Holmbeck, & Greenley, 2002), increased sensitivity to social evaluation, and increased interest in peer relationships (Brown, 2004; Furman, 2002; O'Brien & Bierman, 1988; Steinberg & Morris, 2001). These behavioral changes have been linked with concomitant neurobiological brain changes (Giedd, 2008). Although some findings around adolescent risk taking behaviors have been mixed, a comprehensive review of the field concluded that the reward system in the adolescent brain is hyper-responsive (Galvan, 2010). Developmental alterations in the structure and activation patterns of the adolescent brain have also been linked with increased risk for emotional and psychological problems (i.e., anxiety and depression), and with altered functioning in the emotion-linked areas of the brain (Davidson, 2002; Paus, Keshavan, & Giedd, 2008; Sotres-Bayon, Bush, & LeDoux, 2004).

Changes in sleep need and sleep architecture are also evident during this developmental period. Adolescents need over 9 hours of sleep per night (Carskadon et al., 1980; Paruthi et al., 2016). During adolescence, children also experience an approximately 66% decrease in slow wave sleep relative to childhood (Campbell & Feinberg, 2009; Colrain & Baker, 2011). In addition, slow wave activity (SWA), an indicator of the intensity of slow wave sleep, decreases by about 60% between 11 and 16 years of age (Campbell & Feinberg, 2009; Jenni & Carskadon, 2004). Rapid eye movement (REM) sleep decreases in amount for teens, but unlike observed reduction in slow wave sleep, the percentage of the total sleep period spent in REM does not change with the onset of adolescence (Ohayon, Carskadon, Guilleminault, & Vitiello, 2004). These developmental changes in sleep architecture are thought to signify the extensive changes and major reorganization of the brain during adolescence, including decreased synaptic density (Feinberg & Campbell, 2010), increased prefrontal cortex (PFC) volume (Casey et al., 1997), and increased connectivity between emotion and executive functioning centers of the brain (Gee et al., 2013; Schumann et al., 2004).

A reliable shift in circadian preference or chronotype (i.e., the preferred behavioral pattern of an individual's sleep and wake times) also occurs during adolescence (Jenni, Achermann, & Carskadon, 2005). In childhood, most youth identify with a morning-chronotype of early rise-times and early bed-times (Carskadon, Acebo, Richardson, Tate, & Seifer, 1997). With the onset of puberty however, youth shift toward an evening-chronotype which sometimes causes delayed circadian phase sleep (Jenni et al., 2005). Delayed circadian phase sleep is defined as a pattern of sleep-wake behavior in which both bedtime and wake time are significantly delayed (e.g., 4:00am bedtime, 1:00pm wake time). As most adolescents awaken early in the morning to attend school, the presence of a circadian phase delay and/or an evening-chronotype creates problematic next day consequences for school attendance and performance, driving, and cognitive processing (Bryant & Gómez, 2015). Although circadian phase delay is a clinical condition often requiring both behavioral and medical intervention, adolescents and adults with an evening-chronotype are at greater risk for developing internalizing problems and disorders (Giannotti, Cortesi, Sebastiani, & Ottaviano, 2002), in addition to accumulating next-day "sleep debt" (Bryant & Gómez, 2015). For adolescents, an evening-type circadian preference coupled with increased risk for internalizing problems may contribute to the greater prevalence of affective disorders following the onset of puberty (Angold, Costello, & Worthman, 1998; Campbell, Neill, & Lory, 2012; Hankin et al., 1998; Mezulis, Priess, & Hyde, 2011; Tonetti, Fabbri, & Natale, 2008). Together, circadian changes with the onset of puberty (Jenni et al., 2005) and the increased risk of internalizing problems among adolescents (Giannotti et al., 2002) suggests that targeting adolescent sleep behaviors could meaningfully reduce risk for internalizing psychopathology during this developmental period.

In addition to biological influences that may interfere with sleep in the context of early school start times, technology use also infringes upon adolescent sleep quality. Text messaging and cell phone use in the bedroom during the evening and late night hours interfere with sleep, as 13.4% of 1st graders and 20.8% of 4th graders reported being woken by an incoming text message one to three times a month (Van den Bulck, 2003). Additionally, youth experiencing at least occasional awakenings due to text messages reported being more tired in general, at school, and after the weekend (Van den Bulck, 2003). Television viewing and having a TV in the bedroom have also been associated with increased sleep onset latency (i.e., greater time spent in bed before falling asleep), greater bedtime resistance, more anxiety around sleep, and shortened sleep duration (Owens et al., 1999). Research on computer games yields similar findings, with increased computer game use linked with greater physical symptoms of sleep deprivation including muscular stiffness and blackness under the eyes (Tazawa & Okada, 2001).

Technology use appears to both disrupt sleep (i.e., nighttime text messages), and delay sleep via nighttime exposure to blue spectrum light from screens. The internal sleep-wake clock is highly sensitive to this spectrum of light (Brainard et al., 2001; Thapan, Arendt, & Skene, 2001), and some evidence suggests adolescents are more sensitive to the phase delay effects of blue spectrum light than children (Hagenauer, Perryman, Lee, & Carskadon, 2009). Youth who are involved in TV, computer games, and e-conversations with peers close to bedtime also remain more emotionally activated than peers with good sleep hygiene (Cain & Gradisar, 2010; Carskadon, 2011). Together, the pressures of school, the high accessibility of technology, and the potentially exacerbating effects of increased technology exposure on the adolescent drive for circadian phase delay (i.e., blue light exposure) present a plethora of barriers that interfere with adolescents getting the recommended 9 hours of sleep (Paruthi et al., 2016).

Finally, with the onset of adolescence, teens begin to spend less time with their parents and more time with their peers (Steinberg & Morris, 2001). Specifically, unsupervised contact with peers increases (Brown, 1990), while parents typically provide more opportunities for independent decision making during adolescence (Baumrind, 1991). With increasing age, parents are less likely to set bedtimes for their children (Carskadon, 1990). Research has nonetheless linked the presence of a parentally set bedtime with better and longer sleep, and with less sleepiness during the day relative to youth without set bedtimes (Short et al., 2011). Together, data suggest sleep to be one domain in which adolescents would highly benefit from continued parental supervision.

Impact of Inadequate Sleep on Functioning

Research has linked inadequate sleep with poor motor performance (i.e., decreased reaction time, lower vigilance levels), poor cognitive performance (i.e., increased cognitive distortions) and mood problems (i.e., subjective reports of mood), with mood being the most negatively impacted (Pilcher & Huffcutt, 1996). In adults, experimental sleep restriction across several nights causes cumulative decrements in mood (Dinges et al., 1997) and subjective increases in pain (Haack & Mullington, 2005; Haack, Sanchez, & Mullington, 2007). Cumulative partial sleep restriction studies suggest individuals cope more effectively during cumulative partial sleep restriction than when totally deprived of sleep, as measures of psychomotor vigilance and subjective sleepiness appear to plateau after two days of chronic sleep restriction (Dinges et al., 1997; Drake et al., 2001). However when chronic sleep restriction across 14 nights was directly compared to several night of total sleep deprivation, results revealed similar performance levels on cognitive tasks across groups after two days of restriction (Van Dongen, Maislin, Mullington, & Dinges, 2003). Specifically, there was a near linear relationship between behavioral alertness and cumulative wake time above and beyond 15.84 hours, suggesting cumulative wakefulness, rather than lack of sleep, caused cognitive impairments in both groups (Van Dongen et al., 2003). These discrepant interpretations of results may be related to findings suggesting cognitive performance after chronic sleep restriction varies depending on the specific amount or dosage of restriction (Belenky et al., 2003; Drake et al., 2001). Specifically, individuals who slept 5 hours or 7 hours each night for one week did not show significantly worse performance on psychomotor vigilance tasks, while individuals who slept 3 hours per night for 7 days showed impaired performance (Belenky et al., 2003). Additionally, results from these studies may vary depending on individual differences in susceptibility to fatigue, mood, cognitive processing, and subjective sleepiness problems due to sleep deprivation (Van Dongen, Baynard, Maislin, & Dinges, 2004).

Although some sleep appears better than no sleep, sleep restriction has been linked with several problematic behaviors in adolescence. Home-based experimentally restricted sleep protocols in adolescents have shown positive associations between sleep loss and problems in the domains of inattention, oppositionality and irritability, behavioral regulation skills, and metacognition (Beebe et al., 2008). Lower grades are associated with shorter school-night sleep amounts and with greater variability in sleep across weekends and weekdays (Wolfson & Carskadon, 2003). In a within-group experimental study, teachers blinded to sleep patterns of their students rated sleep deprived students higher on domains of academic difficulty and attention problems in comparison to when the same students received idealized sleep (Fallone, Acebo, Seifer, & Carskadon, 2005).

Silliness and child-like behaviors have been associated with sleep deprivation (Horne, 1993) and a correlational study found that adolescents sleeping less than 8 hours also experienced increased suicidal behaviors (Liu, 2004). Together, findings suggest inadequate sleep negatively impacts cognitive performance, academic performance, and increases emotional and behavioral problems that interfere with day-to-day functioning in adolescence. However these impairments may worsen when adolescents with inadequate sleep are presented with additional demands, such as coping with frustrating situations.

Tolerating frustrating activities is a behavioral skill often called upon in adolescence. Conceptualized as a measure of flexibility in the presence of adverse stimuli, low frustration tolerance is believed to reflect an irrational belief that an aversive situation cannot be adapted or tolerated (Kassinove, 1986). In general, frustration tolerance calls upon the ability to respond to frustrating situations with socially appropriate behaviors that account for the immediate and long term consequences of one's actions (Damasio, 1994). These processes map directly onto emotion regulation, planning, and inhibitory related regions of the brain (Damasio, 1994).

Limited work has explicitly focused on how sleep impacts frustration tolerance. In a within-subjects experimental sleep deprivation study in young adults, responses on a semi-projective measure of frustration tolerance targeting social interactions (Rosenzweig Picture-Frustration Study; Rosenzweig, 1978) revealed that 55 hours of sleep deprivation reduced participant capacity to inhibit impulses (Kahn-Greene, Lipizzi, Conrad, Kamimori, & Killgore, 2006). Specifically, inhibition of aggressive and hostile impulses in response to a frustrating interaction were impaired (Kahn-Greene et al., 2006). Participants showed an increased tendency to blame others for problems, a reduced willingness to alleviate conflict by accepting blame, and a greater number of uncommon responses, indicative of increased frustration levels (Kahn-Greene et al., 2006). Additional studies have observed increased subjective ratings of frustration after 24 hours of total sleep deprivation in comparison to well rested controls (Vasile, Anitei, Chraif, Aniţei, & Liliana, 2013), and when within-subject comparisons are utilized (Chelette, Albery, Esken, & Tripp, 1998). Together, results suggest that inadequate sleep both increase subjective experiences of frustration and impair inhibitory skills called upon during frustrating situations. Building on the negative consequences of inadequate sleep on behavioral functioning, adolescent functioning in the presence of chronic sleep loss (NSF, 2006) may be further worsened by changes in emotion and emotion regulation that also occur during this developmental period.

Emotion and Emotion Regulation in Adolescence

Adolescence is a time of change, including changes in emotion and emotion regulation skills. Various bodies of research have demonstrated changes in the intensity and neurobiological underpinnings of emotion during the adolescent years. In longitudinal examinations of emotion, emotional states become generally less positive across early adolescence (Larson, Moneta, Richards, & Wilson, 2002). However this pattern appears to stop around 10th grade, suggesting late adolescence is associated with a gradual slowing of the emotional changes of early adolescence (Larson et al., 2002). Further, collective findings suggest an increase in affective processing in the brain beginning around mid-adolescence (Crone & Dahl, 2012). Consistent with longitudinal behavioral changes in emotion, functional imaging results suggests adolescents process emotional information differently than adults (Yurgelun-Todd, 2007). Moreover, emotion centers of the brain, including the amygdala and connective pathways from the amygdala to the prefrontal cortex (PFC), also experience significant growth from childhood through adolescence (Gee et al., 2013; Schumann et al., 2004). Improvements in emotional capacity (compared to childhood) are also characteristic of this developmental period, including improvements in affect modulation and in discriminating among emotional cues (Yurgelun-Todd, 2007), which are particularly essential for effective emotion regulation skills.

Building on the observed neurobiological and longitudinal behavioral changes in emotion across adolescence, a number of lab-based studies suggest that objective measures of emotional reactivity remain consistent across development, while emotional regulation skills (i.e., cognitive reappraisal) improve with age (McRae et al., 2012; Silvers et al., 2012). Broadly, emotional reactivity is defined as an individual's behavioral and physiologic responses to an emotion, while emotion regulation is defined as the process through which individuals modulate or alter their emotional experiences (Gross, 2013). One study assessed both subjective report of emotional reactivity and fMRI amygdala activation in response to images from the International Affective Picture System (IAPS; Lang, Bradley, & Cuthbert, 2008) to understand how emotional reactivity and cognitive reappraisal (a form of emotion regulation) develop across adolescence (McRae et al., 2012). Young adolescents, older adolescents, and adults were asked to either react to (i.e., "look") or reappraise (i.e., "decrease") their emotional response to specific negative and neutral images from the IAPS (McRae et al., 2012). Findings revealed that cognitive reappraisal ability increased with age, yet there were no age related differences in emotional reactivity on self-report or amygdala activation measures (McRae et al., 2012). Additionally, social processing regions of the brain were less active during reactivity trials than regulation trials (McRae et al., 2012).

In a similar study by Silvers and colleagues (2012), individuals 10 to 23 years of age were asked to either reappraise (i.e., "decrease") or react to (i.e., "look") IAPS images and rate their emotional responses. Similar to previous findings, emotional reactivity was consistent across ages, but emotion regulation skills were positively associated with age (Silvers et al., 2012). This study also identified emotion regulation skills in younger adolescents were more negatively affected by social situational factors and having higher levels of rejection sensitivity (Silvers et al., 2012). These overall findings are consistent with observed structural and functional brain changes during adolescence including normative increases in prefrontal cortex volume and associated increases in behavioral inhibitory abilities (Casey et al., 1997). Increased cognitive control combined with adolescents' improved ability to read social cues (Herba & Phillips, 2004; Perlman & Pelphrey, 2011) contribute to the growth seen in emotion regulation skills, which call upon working memory, inhibitory control, abstract thought, decision making, and perspective taking skills (Ahmed, Bittencourt-Hewitt, & Sebastian, 2015). Together, it is evident that experimental sleep research examining aspects of emotional reactivity and emotion regulation may be most informative in understanding how inadequate sleep may alter affective risk during adolescence.

Gross' modal model of emotion. The construct of emotion has been defined in many different ways and is often used interchangeably, albeit incorrectly, with affect and mood. Following Gross's (2015) process model of emotion, the current project refers to emotion as one of several subordinate aspects of affect (Gross, 2015b). Affect is a broader construct defined as various states that relate to relatively quick value discriminations (Scherer, 1984). It is composed of several subordinate features including stress responses, emotions, and moods (Gross, 2015b). Stress responses are regarded as a classification of negative but non-specific affective states, whereas emotions are more specific (Gross, 2015b). Similarly, emotions differ from moods in their intensity and stimuli; emotions are evoked by specific situations or events, while moods last longer and are often more diffuse than emotions (Gross, 2015b). Moods have been shown to bias cognition and behavior (Gendolla, 2000; Siemer, 2001), but emotion is more directly related to behavioral response tendencies, which are highly relevant in the behaviors of adolescents.

Emotions are defined as linked changes across subjective experience, behavior, and physiology occurring over time (Gross, 2015b). Gross' *Modal Model of Emotion* identifies emotion generation as an intricate process occurring across many different levels of individual experience. The *Modal Model of Emotion* includes several stages through which *emotion generation* and subsequent *emotion regulation* occur. Emotion generation is defined as a four-stage process, beginning when an individual encounters a *situation* or stimulus that evokes an emotion. The next step in the model involves deployment of *attention*, followed by a cognitive *appraisal* of the situation. The last and final stage of the emotion generative process is the *behavioral response*, in which the individual exhibits a behavioral reaction to the emotion generated (Gross, 2013).

Emotion regulation. Emotion regulation occurs within this emotion generative framework. Emotion regulation is defined as the different individual actions that influence what emotions are experienced, at which times, and how these emotions occur (Gross, 2015a). Gross' *Process Model of Emotion Regulation* builds off the *Modal Model of Emotion*, identifying 5 points within the emotion generative process at which emotion can be regulated. These points include *situation selection, situation modification, attentional deployment, appraisal of the situation,* and *response modulation* (Gross, 2013).

Situation selection refers to the active selection of, or avoidance of, a given environment that may evoke particular emotions (Gross, 2013). For example, individuals who enjoy and derive pleasure from social interaction may choose to attend a greater number of social events. *Situation modification* is defined as a modification of one's external environment that subsequently alters one's emotional experience of the situation (Gross, 2013). For example, individuals use situation modification when they invoke humor to diffuse tense social settings that cause anxiety. Situation modification can take on other forms as well, such as use of clear emotional expressions to better communicate one's feelings to others (Gross, 2013). Much like the selection of a particular situation, modification of a situation creates opportunities to experience or avoid certain emotions.

Attentional deployment is a cognitive emotion regulation strategy in which the individual directs their attention in a specific way to either increase or decrease an emotion (Gross, 2013). Individuals often use distraction to deploy their attention elsewhere, either by diverting their attention to other stimuli in the current situation or by shifting their internal focus away from the present situation entirely (Gross, 2015a). For example, when sitting in a frustrating meeting, individuals may shift their focus to a more neutral aspect of the room to reduce feelings of frustration or they may shift their internal focus to a positive memory to increase pleasurable feelings.

Cognitive change is a regulation strategy that occurs during the appraisal phase, in which the individual consciously alters cognitions linked with their emotional response (Gross, 2013). For example, an individual who is concerned about a friend not answering the phone may reappraise their original thought that their friend was in an accident to the thought "they're in the bath" in order to reduce fearful emotions. It is important to note that *situation modification* differs from *cognitive reappraisal*, as *situation modification* includes efforts to modify one's external environment, while *cognitive reappraisal* is the modification of one's internal thought processes (Gross, 2015a). Finally, *response modulation* involves the direct alteration of one's physiological, experiential and/or behavioral responses after an emotion has been fully generated (Gross, 2013). Because response modulation aims to alter already-present emotions, fewer opportunities for alteration are available and greater efforts may be needed to achieve the aim of modulation.

The current study is designed with a specific focus on the emotion regulation strategy of *situation modification.* This aspect of Gross's model was chosen for two reasons. First, sleep research involving experimental manipulations of sleep, both in adolescents as well as adults, have rarely examined the use of this strategy for regulating one's emotional responses (Gross, 2015a). However, because this strategy occurs relatively early in the emotion-generative process, it may be more effective in altering emotional responses than modulation strategies attempted further "downstream" (i.e., cognitive reappraisal). Second, inadequate sleep has been shown to have significant effects on emotional expression. For example, sleep-restricted youth show more negative emotion and less positive emotion (Berger, Miller, Seifer, Cares, & Lebourgeois, 2012). Similarly, sleep deprived adolescents and adults show less positive affect relative to when well rested (Talbot et al., 2010). Because impairments in social expression have been associated with sleep loss (Beattie, Kyle, Espie, & Biello, 2015), development and utilization of appropriate social emotional expression may be particularly essential, and challenging, during adolescence when sleep deprivation is high (Owens, Dearth-Wesley, Lewin, Gioia, & Whitaker, 2016) and peer relationships are greatly important (Steinberg & Morris, 2001).

It is also critical to note that measuring actual emotion regulation is not possible without first considering ones' emotional goals. That is, an individual must first desire to regulate or modify his/her emotional experience in some way before the effectiveness of any particular regulatory strategy can be determined (Mauss & Tamir, 2013). These goals can be non-affective goals (i.e., in which the desired outcome is not an explicit affective state), affective goals (i.e., in which the desired endpoint is positive or negative), or emotional goals (i.e., in which a specific emotional state serves as the direct desired endpoint; Mauss & Tamir, 2013). Unfortunately, much of previous emotion regulation research has not accounted for the presence/absence of specific emotional goals. In light of this, the current study specifically manipulated the emotional goals of participants as part of a lab-based emotion regulation task.

Impact of Inadequate Sleep on Emotion

Impact of inadequate sleep on subjectively reported emotion and mood. Sleep loss can severely impact individual emotional functioning across a range of domains. Changes in state-based emotion and mood have been observed in the context of inadequate sleep. In adolescence, sleep restricted healthy youth rate themselves on measures of mood (i.e., POMS) as more anxious, angry, and confused in comparison to their ratings when well rested (Baum et al., 2014). These within-group differences in mood were significant although sleep had only been restricted by an average of 2.5 hours each night (Baum et al., 2014), suggesting that relatively minor sleep restriction (i.e., 6.5 hours in bed) had a large impact on subjective adolescent mood. Talbot and colleagues (2010) examined emotion following experimental sleep deprivation across younger adolescents, older adolescents and adults. Decreased state levels (i.e., "right now") of positive affect (using the Positive and Negative Affect Schedule – Child [PANAS-C]; Watson, Clark, & Tellegen, 1988) when sleep deprived were observed across all age groups relative to their own rested reports (Talbot et al., 2010). In a study based on the same dataset, sleep deprived youth reported less positive affect relative to their well rested reports (Dagys et al., 2012). Notably, this within-subject difference was larger for youth who preferred an evening-type schedule (Dagys et al., 2012). In Paterson and colleagues' (2011) study, participants deprived of sleep for one or two nights reported significantly less frequent, less intense self-reports of happiness on hourly mood measures and more intense self-reported negative mood in comparison to well rested controls (Paterson et al., 2011). Sleep deprived adults experienced decreased subjective levels of positive affect (via the PANAS) in comparison to well rested controls, however subjective reports of negative affect (via the PANAS) were not significantly different across groups (Franzen, Siegle, & Buysse, 2008). In a study comparing sleep restricted adolescents to SE (i.e., 10 hours in bed), McMakin and colleagues (2016) observed increased self-reported state-levels of negative affect (i.e., intensity ratings of sad, tense, anxious, stressed & irritable) and decreased state-levels of positive affect (i.e., intensity ratings of happy, calm, relaxed) following sleep restriction relative to SE (McMakin et al., 2016).

The impact of increased sleep duration on aspects of emotional functioning has received limited attention, although brief naps have been shown to increase positive mood ratings in healthy adults (Kaida, Takahashi, & Otsuka, 2007; Luo & Inoué, 2000) and evening sleep extension in healthy teens has been associated with improved mood (Van Dyk et al., 2017). In one study that randomized adults to nap and no-nap groups, subjective ratings of positive mood in the no-nap group decreased across the day whereas such changes were not observed in the nap group (Gujar, McDonald, Nishida, & Walker, 2010). In a recent study evaluating the feasibility of a 1.5 hour evening sleep extension among "short sleeping" adolescents (i.e., teens typically sleeping 5-7 hours per night) via sifting bedtimes earlier, adolescent reported decreased ratings of anger, fatigue, confusion and increased ratings of vigor on the POMS following SE relative to typical sleep (Van Dyk et al., 2017). Collectively, findings for self-reported mood and affect suggest that both decreased positive mood and increased negative mood occur following sleep deprivation/restriction relative to when participants are well rested. However, emotional reactivity within the context of adolescent peer interactions has not been examined.

Impact of inadequate sleep on subjective emotional reactivity. Defined to include both behavioral and physiologic responses to emotion-relevant information/events (Gross, 2013), a number of experimental studies have examined associations between subjectively measured emotional reactivity and inadequate sleep. When healthy adolescents were shown positively, negatively, and neutrally-valenced IAPS images after several nights of optimized sleep (i.e., 10 hours) or after a night of restricted sleep (i.e., 4 hours), participants with restricted sleep reported higher levels of negative emotional reactivity (i.e., anger, sadness, fear) in reaction to negative images (Leotta, Carskadon, Acebo, Seifer, & Quinn, 1997). However, there were no differences found on subjectively reported measures of emotional valence and arousal ratings for each image (Leotta et al., 1997).

Consistent with these data, Reddy and colleagues (2016) observed a trend towards increased negative ratings of negatively-valence images among adolescents with restricted sleep (i.e., approximately 4 hours of sleep) relative to idealized sleep (i.e., 8-9 hours of sleep; Reddy et al., 2016). In a study assessing emotional reactivity in response to a worry task, experimentally sleep deprived participants from young adolescence to adulthood were asked to catastrophize and younger adolescents, but not older adolescents and adults, appraised their greatest worry as significantly more threatening when sleep deprived relative to when well rested (Talbot et al., 2010).

Similar to adolescents, the link between sleep and emotional reactivity has been well established in adults (Franzen et al., 2008; Minkel, Htaik, Banks, & Dinges, 2011; Paterson et al., 2011; Wagner, Fischer, & Born, 2002). In a comparison of sleep restriction during the first and the second halves of the night, Wagner and colleagues (2002) found that adult males who were deprived of sleep in the second half of the night had increased emotional responses to negative pictures from the IAPS. The authors attribute this finding to deprivation of REM, as REM predominantly occurs during the second half of the night (Wagner et al., 2002). Another study found no subjective differences in emotional reactivity across sleep deprived and well rested participants in response to viewing amusing and sad videos (Minkel et al., 2011).

Although sleep extension paradigms have received limited attention in the literature, naps have been shown to promote effective emotional reactivity in response to viewing emotional faces (Gujar et al., 2010) in healthy adults. When adults were randomized to nap and no-nap groups, and asked to appraise the intensity of faces across several categories of emotion (i.e., anger, fear, sad, happy), those who napped demonstrated a reduction in their subjectively reported appraisal of fearful faces after their nap, while subjective reactivity ratings increased in the no-nap group (Gujar et al., 2010). The intensity of anger ratings in response to angry faces in the no-nap group became amplified across the day, but this amplification was absent in the nap group (Gujar et al., 2010). Additionally, individuals who napped appraised the emotional intensity of happy faces as increased (i.e., happier) following the nap, while there was no change in the no-nap group (Gujar et al., 2010). Further, young children deprived of a napping opportunity demonstrated increased emotional reactivity (confusion) in response to neutral pictures, more negative emotional reactivity in response to neutral pictures, and less positive emotional reactivity in response to positive pictures than when viewing images well rested (Berger et al., 2012).

Collectively, subjectively reported emotional reactivity findings suggest that inadequate sleep increases negative reactivity and decreases positive emotional reactivity, although a few studies have presented mixed/null findings (Leotta et al., 1997; Reddy et al., 2016). Moreover, limited research investigating sleep extension via naps in adults and children suggests that more sleep may increase positive emotional reactivity and decrease negative emotional reactivity (Berger et al., 2012; Gujar et al., 2010). However, subjectively reported emotional reactivity often differs from objective measures of emotional reactivity. Indeed, inadequate sleep has been linked with brain-based changes in emotional reactivity that underpin both subjective and objective components of emotional reactivity and emotion regulation.

Impact of inadequate sleep on objective emotional reactivity.

Neurobiological outcomes. On a neurobiological level, sleep deprivation amplifies activity in reward networks of the brain, leading to increased emotional lability (Gujar, Yoo, Hu, & Walker, 2011). Consistent with these findings, Yoo and colleagues (2007) observed significantly increased activity in the amygdala (an area known as the emotion center of the brain) among sleep deprived individuals relative to well-rested controls. In the same study, activation in the PFC, an area known to exert top down control over various executive functions including emotion regulation, was reduced in sleep deprived individuals. Communication between the amygdala and PCF was also impaired following sleep deprivation (Yoo, Gujar, Hu, Jolesz, & Walker, 2007).

Findings from sleep deprivation studies are bolstered by research utilizing partial sleep restriction paradigms. When sleep is chronically restricted to 4 hours per night (across 5 nights) in healthy adults, amygdala reactivity increases in response to fearful faces, but not in reaction to viewing positive faces (Motomura et al., 2013). Additionally, impairment in amygdala-PFC connectivity has been linked with greater impact of emotional distraction on working memory in sleep deprived adults (Chuah et al., 2010; Motomura et al., 2013). Together, results suggest both partial sleep restriction as well as total sleep deprivation impair memory and reactions to emotional stimuli at the neurobiological level.

Observational studies in children utilizing fMRI data (for males only) have also demonstrated increased neural activity in emotion centers of the brain (i.e., bilateral amygdala, insula, and temporal lobe) in response to fearful and disgusting images; this relationship also appears to be amplified among children with a shorter sleep duration (Reidy, Hamann, Inman, Johnson, & Brennan, 2016). Furthermore, children with a short sleep duration were observed to have less brain interconnectivity when examined via fMRI (Reidy et al., 2016), similar to the findings of Yoo and colleagues (2007). These neurobiological reactions to inadequate sleep across adults and children lay the foundation for the observed changes in objectively assessed emotional reactivity among sleep deprived/restricted individuals.

Physiological outcomes. When completely deprived of sleep for one night, adults exhibit increased physiological emotional reactivity in the form of pupillary response to emotional images from the IAPS in comparison to well rested controls (Franzen et al., 2008). In an expanded study by the same research group, sleep deprived adults were observed to experience increased pupillary response to negatively valenced pictures (Franzen, Buysse, Dahl, Thompson, & Siegle, 2009). When sleep deprived and well rested participants in this study were compared on their pupillary response speed, increased emotional reactivity began with stimulus onset in the well-rested group, whereas sleep deprived individuals began reacting to a pre-stimulus warning cue during negatively valenced trials (Franzen et al., 2009). This finding suggests emotional conditioning of negative information occurs more quickly for sleep deprived individuals (Franzen et al., 2009).

Recently, examinations of pupillary measures of emotional reactivity have been expanded into adolescents. McMakin and colleagues (2016) conducted two similar, but separate experiments examining aspects of objective emotional reactivity. The first experiment presented in McMakin and colleagues (2016) examined pupillary reactivity in response to emotionally valenced sounds (e.g., negative, positive, neutral) following both SE (i.e., 10 hours in bed for 2 nights) and sleep restriction (i.e., 4 hours in bed for 2 nights); conditions were counterbalanced within participants with a 5 day washout period between conditions. Relative to SE, increased pupillary reactivity in response to negative sounds was observed after two nights of sleep restriction. In the second experiment, McMakin and colleagues (2016) also examined a more severe but equally dosed sleep restriction paradigm (i.e., 6 hours of sleep on night 1; 2 hours in bed on night 2) relative to SE (i.e., 10 hours in bed for 2 nights). Consistent with the first experiment, pupillary emotional reactivity was increased in response to negative sounds following sleep restriction. A peer interaction task was also completed on day 2 of the second experiment (i.e., participants discussed two conflicts with a peer present at the study visit for 5 minutes), and negative affective behavior during the peer conflict task was significantly elevated following sleep restriction relative to SE. Together, findings from both experiments suggest that adolescent pupillary emotional reactivity may map onto social affectivity in the context of sleep restriction (McMakin et al., 2016).

Additional research has examined biological markers of emotional reactivity in the context of inadequate sleep. Cortisol, a hormone known to signal physiological stress, increases after sleep deprivation (Minkel et al., 2014). Notably, cortisol levels in sleep deprived individuals exposed to a stressful task were significantly elevated in comparison to well rested controls (Minkel et al., 2014). These group differences in cortisol levels were significant at both the morning time point (after sleep/sleep deprivation) and later during the stressful task (Minkel et al., 2014). Findings suggest sleep deprivation increases objectively measured stress (i.e., cortisol) both in reaction to stress and following sleep deprivation. Heart rate and blood pressure changes have also been linked with sleep related problems. In a study of healthy adults assessing cardiovascular autonomic modulation during 36 hours of continuous sleep deprivation, sleep deprived individuals had increased sympathetic and decreased parasympathetic cardiovascular modulation in comparison to controls (Zhong et al., 2005). Relative to controls, sleep deprived individuals also showed decreased spontaneous baroreflex sensitivity, which is a negative feedback loop designed to maintain blood pressure stability (Zhong et al., 2005).

Other objective outcomes. Further, objective measurement of emotional reactivity has been expanded into objectively assessed behaviors, including facial expressions and emotional language. In a study assessing facial expression emotional reactivity (coded using the Facial Expression Coding System [FACES]; Kring & Sloan, 2007), sleep deprived participants had less overall facial expressiveness relative to well rested controls (Minkel et al., 2011). Although significant group differences in subjectively-assessed emotional reactivity were not observed, objective results suggest that facial expression emotional reactivity was "blunted" by sleep deprivation (Minkel et al., 2011). Specifically, participants displayed less overall expressivity in response to emotional movie clips (i.e., less positive expression to clips evoking amusement; less negative expression in response to clips evoking sadness) following a night of sleep deprivation (Minkel et al., 2011). In the one study to objectively assess emotional reactivity via vocal expression (using computerized language analysis in Linguistic Inquiry and Word Count [LIWC] program) during an interview following a night of severe sleep restriction (i.e., max 2 hours of sleep), adolescents used fewer positive emotional words following sleep restriction relative to when rested the night before (McGlinchey et al., 2011). Similar to findings from Minkel and colleagues (2011), objective language based assessment of emotional reactivity suggests that sleep deprived adolescents exhibited a "blunting" of emotional reactivity following sleep loss (McGlinchey et al., 2011).

Collectively, objective results suggest that sleep deprivation/restriction increases emotional reactivity in the form of physiologic responses to negative stimuli (Franzen et al., 2009) but blunts (i.e., dampens) emotional reactivity observed via facial expression and language based behaviors (McGlinchey et al., 2011; Minkel et al., 2011). Further, results suggest that sleep deprivation/restriction impairs parasympathetic regulatory systems (Zhong et al., 2005). Preliminary evidence suggests similar patterns of objective emotional reactivity are present in sleep restricted adolescents (McGlinchey et al., 2011; McMakin et al., 2016). Across measures of emotional reactivity, the impact of inadequate sleep on emotion and emotion regulation is important to consider in the context of adolescent peer interactions and relationships, especially as peer relationships are particularly salient during this developmental period (Steinberg & Morris, 2001).

Social Implications of Sleep and Emotion Regulation Problems

Although emotion regulation is often conceptualized as an individually-based process, as in Gross' *Process Model of Emotion*, it is also a process that often occurs within social environments (Campos, Campos, & Barrett, 1989; Walden & Smith, 1997). Emotion regulation has been examined experimentally in adolescents via evoking cognitive appraisal skills in reaction to pictures from the IAPS (McRae et al., 2012; Silvers et al., 2012), however the examination of emotion regulation skills within the context of sleep loss/extension has received limited empirical attention. A recent examination of emotion regulation in healthy adolescents via a cognitive reappraisal task (i.e., assessed after viewing IAPS images) found no differences across sleep restricted and idealized sleep groups on cognitive appraisal ability (i.e., both groups were able to effectively use the technique; Reddy et al., 2016). However, it is important to note that these experimental approaches to emotion regulation are highly structured, and emotion regulation within these paradigms likely differs from true emotion regulation skills that adolescents utilize in naturalistic social environments.

Indeed, emotion regulatory skills are important for promoting adaptive responses in different social situations (Salovey, Mayer, Caruso, & Yoo, 2002). Among college students, those who report greater skill in managing their emotions were more likely to report positive relationships with others (Lopes, Salovey, & Straus, 2003). In youth, emotionally-based skills such as emotion identification of others' facial expressions, understanding affective messages, and expressing emotion were linked with social competence (Halberstadt, Denham, & Dunsmore, 2001). However research examining the impact of sleep on emotional mechanisms of social competence is relatively unavailable.

In a study assessing the relationship between behavioral problems and sleep, child social difficulties were significantly correlated with specific sleep problems including parasomnias, enuresis, insomnia, and tiredness (Stein, Mendelsohn, Obermeyer, Amromin, & Benca, 2001), suggesting that some disruption of sleep may negatively impact social effectiveness. In fact, social problems alone accounted for 22% of the variance in parasomnias and 11% of the variance in tiredness problems within this sample (Stein et al., 2001). In adults, earlier sleep onset is positively associated with better social interaction experiences the next day (Totterdell, Reynolds, Parkinson, & Briner, 1994). Similarly, another study found sleep quality to be significantly correlated with friendliness the following day (Kramer, Roehrs, & Roth, 1976). Decreased social cooperation, social interest, and social competence are seen in adults deprived of sleep for 205 hours (Pasnau, Naitoh, Stier, & Kollar, 1968) and an inverse association between sleep duration and interpersonal difficulties has been observed in medical residents (Baldwin & Daugherty, 2004).

Examinations of REM sleep after sleep deprivation suggests that REM sleep during the night predicts individual's ability to discriminate social emotions in others on the following day (Goldstein-Piekarski, Greer, Saletin, & Walker, 2015). Further, sleep deprived individuals in this study categorized more faces as threatening relative to when participants were well rested. On the neurological level, the anterior insula and the dorsal anterior cingulate cortex (dACC) were significantly activated during tasks in which participants discriminated threatening from non-threatening faces when well rested, but these same activations were not seen under sleep deprived conditions. Findings suggest sleep loss impairs the brain's ability to distinguish between a variety of social cues within the vicorosensory cortical regions of the dACC and the insula; authors proposed that decreased activation in these areas caused the conservative behavioral approach of categorizing a greater number of faces as threatening (Goldstein-Piekarski et al., 2015). Such poor sensitivity to social cues in the context of sleep loss is particularly problematic for teens who are still developing these nuanced skills.

A single night of sleep deprivation has also been shown to impact economic preferences in healthy young adults, which likely have social consequences. Specifically, sleep deprivation appears to drive changes in activation within the ventromedial PFC and anterior insula that have a role in decision making; after a night of sleep deprivation, these regions of the brain were more activated following gains, and less activated following losses relative to when participants were well rested (Venkatraman, Huettel, Chuah, Payne, & Chee, 2011). Similar patterns of risk taking have been observed in healthy adults engaging in trust-based games following either a night of total sleep deprivation or a typical night of normal sleep. Within these games, participants deprived of sleep were more likely to reject financial offers that represented an "unequal split", despite the natural consequence of forfeiting the ability to gain any money due to their rejection (Anderson & Dickinson, 2010). In other words, participants who were completely sleep deprived made decisions about accepting and rejecting financial offers based on emotion (i.e., concept of "fairness") rather than monetary gain (Anderson & Dickinson, 2010). In the context of adolescent development, findings from economic preference studies suggest the tendency of sleep-deprived individuals to make emotionally based decision may further amplify social emotional regulation problems for adolescents unable to get enough sleep.

Shift workers who work nights or a rotating shift frequently experience insomnia, excessive sleepiness, and subsequent occupational and health related problems (Drake, Roehrs, Richardson, Walsh, & Roth, 2004). These individuals also report missing social activities more frequently than individuals who work 9-5 and also experience insomnia (Drake et al., 2004). Even in working adults with typical work schedules, insomnia has been associated with increased levels of hostility and fatigue, and lower levels of joy and assertive behaviors (Scott & Judge, 2006).

Not surprisingly, adult "optimal sleepers" (who sleep an average of between 6 to 8.5 hours per night) have more positive relations with others, higher rated levels of self-acceptance and purpose in life, and lower levels of depressive symptoms compared to individuals sleeping either less than 6 or greater than 8.5 hours per night (Hamilton, Nelson, Stevens, & Kitzman, 2007). Given the implications of inadequate sleep on neurobiological, physiological, behavioral, and affective components of emotion, the restorative effect of sleep on emotion regulation skills appears to directly impact the quality of social interactions across the day. Relations between sleep and emotional functioning and between emotional functioning and social interaction have been well established, yet the impact of sleep on socially based emotion regulation has yet to be examined.

The Current Study

Building on existing research, the current study sought to examine the potential protective impact of extended sleep on socially-based emotional regulation skills in adolescence. Although a large body of research has confirmed the detrimental emotional impact of sleep restriction on various aspects of functioning, the superordinate goal of all clinical science should be to promote health through either prevention or intervention efforts. In order to fully understand the impact of sleep on adolescents' emotional functioning, direct evidence showing “more sleep is better” is needed to inform sleep-based prevention/intervention programs.

A small body of research has examined the impact of SE on domains of children’s functioning. In school aged children, increasing sleep duration by only 30 minutes across 3 nights has been shown to yield significant improvements in neuropsychological functioning (Sadeh, Gruber, & Raviv, 2003). A dose-response relationship between consistency of bedtime and sleep quality has also been identified wherein greater (current and historical) bedtime consistency is linked with increased sleep quality in preschoolers and toddlers (Mindell, Li, Sadeh, Kwon, & Goh, 2014). Cumulative SE in youth has also been associated with improvements in emotional lability, restlessness-impulsive behavior and reductions in daytime sleepiness (Gruber, Cassoff, Frenette, Wiebe, & Carrier, 2012). In adolescents with chronic sleep problems, gradually extending sleep by as little as 15 minutes each night was associated with decreased emotional problems (specifically depressive symptoms) with no additional decrease in sleep efficiency (Dewald‐Kaufmann, Oort, & Meijer, 2014).

Because few studies have examined the impact of SE on socio-emotional functioning during adolescence, the current study sought to address this gap by experimentally extending sleep in a community sample of adolescents. The impact of SE on mood, emotional reactivity, and emotion regulation skills were compared to a “sleep as usual” group, which, based on national averages, was expected to get much less sleep than adolescents truly need (Noland, Price, Dake, & Telljohann, 2009).

Within the sleep deprivation/restriction and emotion literature, various subjective (Baum et al., 2014; Chelette et al., 1998; Dagys et al., 2012; Kahn-Greene et al., 2006; Leotta et al., 1997; Minkel et al., 2012; Paterson et al., 2011; Reddy et al., 2016; Talbot et al., 2010;

Vasile et al., 2013; Wagner et al., 2002) and objective measures of emotion (Dinges et al., 1997; Franzen et al., 2009; Minkel et al., 2014; Motomura et al., 2013; Yoo et al., 2007) have been used to assess emotional reactivity and regulation, however only a handful of studies have utilized both subjective and objective measurements together (Dinges et al., 1997; Franzen et al., 2008; McGlinchey et al., 2011; McMakin et al., 2016; Minkel et al., 2011). The current study sought to expand on previous work by using a multimodal battery of emotion, including subjective ratings of emotion and objective scoring of facial expression (using FaceReader; Ekman & Friesen, 1977) and emotional language (using LIWC; Pennebaker, Francis, & Booth, 2001). Although human-coded facial coding systems have been used in the past (e.g., Minkel et al., 2011), the current study's use of a validated, computerized scoring program for both facial expression and language represents a novel approach for assessing objective emotional reactivity.

The current study also utilized an ecologically-valid experimental task. The majority of previous studies have asked participants to view movie clips and react normally (Minkel et al., 2011), to view or to suppress/reappraise reactions to affective images (Berger et al., 2012; Franzen et al., 2009; Gujar et al., 2010; Leotta et al., 1997; Wagner et al., 2002), or to rate specific emotions (Baum et al., 2014; Dagys et al., 2012; Franzen et al., 2008; Kaida et al., 2007; Paterson et al., 2011; Talbot et al., 2010) after sleep deprivation/restriction. However, the extent to which these tasks capture actual emotion regulation skill (i.e., in the absence of explicit instruction and reports of effort) is unknown. Only one study has examined adolescent behavior during an explicit discussion of a peer conflict (McMakin et al., 2016), though re-visiting a peer conflict may not elicit the same emotional reactions as real time conversations.

Further, studies have not assessed the specific emotional goals of participants. In order for emotion regulation to occur, a clear emotional goal must be present (Mauss & Tamir, 2013). As an ecologically-valid context for evaluating the impact of SE on emotion regulation skills, the current study utilized a social task designed to actively engage adolescents toward a specific social-emotional goal. This manipulated social interaction task, in which participants were asked to improve the mood of a peer, was used to measure emotion regulation. The latter interaction also strategically occurred directly after a challenging computer game in order to provide a more robust test of adolescents' ability to up-regulate positive emotion. Use of a challenging computerized task also served as an ecologically-valid measure of frustration tolerance.

Aim 1 – Impact of sleep extension on mood. The primary aim of the current study was to examine the effect of five consecutive nights of SE (i.e., one hour per night) compared to typical sleep (TS; wherein no specific sleep directions were given) on subjectively assessed mood among a sample of adolescents. Mood was assessed in two ways: using the Profile of Mood States-Adolescents (POMS-A; Terry, Lane, Lane, & Keohane, 1999) questionnaire at the baseline appointment and after the five-day sleep manipulation, and using daily reports on a brief mood questionnaire during each day of the baseline sleep week (Phase 1) and the sleep manipulation week (Phase 2). Specific hypotheses included:

a) Relative to Phase 1 (typical sleep), the SE group was expected to report a significant increase in positive mood and a significant decrease in negative mood on the POMS-A following Phase 2 (sleep manipulation). Conversely, the TS group was expected to report consistent levels of positive and negative mood across the two time points.

b) Between-group differences in POMS-A scores were expected after the sleep manipulation as well, including significantly greater ratings of positive mood and significantly less negative mood in the SE group.

c) For daily mood ratings, youth in the SE group were expected to report a significant increase in positive mood (i.e., amused/silly, loving/warm, happy) and a significant decrease in negative mood (i.e., nervous/worried, sad, angry) from Phase 1 to Phase 2. Conversely, compared to Phase 1, the TS group was expected to report consistent levels of positive and negative mood during Phase 2.

Aim 2 –Impact of sleep extension on emotional reactivity during a laboratory-based assessment. The second aim of the current study was to assess the effects of SE on emotional reactivity using both subjective and objective measures of reactivity. Subjective measures of reactivity included self-reported arousal and valence (using the Self-Assessment Manikin [SAM]; Bradley & Lang, 1994) and ratings of frustration following a frustrating computer game task. Objective measurement of emotional reactivity included measurement of facial expression (i.e., valence and variability using FaceReader, where valence was defined as the overall positive vs. negative affect in each participant's facial expression during the frustrating computer task) and emotional language (i.e., frequency of positive words, negative words, and total word count during a naturalistic social interaction). Specific hypotheses included:

a) In comparison to the TS group, the SE group was expected to report less overall subjective reactivity/arousal, higher valence ratings (i.e., less negative), and lower levels of frustration after completing the frustrating computer task.

b) In comparison to the TS group, the SE group was expected to show greater facial expression reactivity (i.e., higher facial expression valence) and greater facial expression variability during the frustrating computer task, consistent with existing research that has demonstrated emotional "blunting" following sleep restriction (McGlinchey et al., 2011; Minkel et al., 2011).

c) In comparison to the TS group, the SE group was expected to use a higher frequency of positive emotional words, a lower frequency of negative emotional words and a higher number of total words during the naturalistic social interaction task.

Aim 3 –Impact of sleep extension on emotion regulation. The third aim of the current study was to assess the impact of SE on emotion regulation within two ecologically - valid situations: social interactions and playing a computer game. To assess emotion regulation skills during a manipulated social interaction task, change in subjectively reported reactivity (arousal and valence), as well as change in emotional language (i.e., positive words, negative words, and total word count) across non-manipulated and manipulated social interaction tasks were assessed. Lastly, to assess emotion regulation during the frustrating computer game, task persistence (in seconds) was assessed. Specific hypotheses included:

a) A significant interaction was expected between SE and TS groups and subjectively reported arousal and valence following the social interaction tasks. Specifically, the SE group was expected to report a significant increase in valence across the naturalistic and manipulated social interaction tasks relative to the TS group. Further, significantly higher ratings of reactivity/arousal were expected in the SE group relative to the TS group across both the naturalistic and manipulated social interaction tasks (i.e., as a result of increased regulatory effort).

b) A significant interaction was expected between SE and TS groups and emotional language used during the interaction tasks. Specifically, in comparison to the TS group, the SE group was expected to have a significantly greater increase in the frequency of positive emotional words, a greater decrease in frequency of negative emotional words, and a greater increase in the total number of words overall when language variables were compared (as repeated measures) across the naturalistic and manipulated interaction tasks.

c) In comparison to the TS group, the SE group was expected to show greater persistence in completing the frustrating computer game (longer duration of play in seconds).

METHOD

Participants

Participants in the current study were recruited from the local community using cold calling to parents of local high school students (contact information was obtained via publicly available student information from several large school districts), as well as posting flyers in public community spaces (i.e., coffee houses, movie theater, dance studios, high schools). In order to participate, a phone screener was completed prior to the first appointment confirming potential participants were: 1) medically healthy, 2) between 13-17 years of age, 3) enrolled in regular education classes (i.e., not special education), and that 4) English was the primary language in the home. Participants were excluded if: 1) a current ICSD-2 (International Classification of Sleep Disorders – 2nd edition; American Academy of Sleep Medicine, 2005) sleep disorder was present or suspected; 2) they had a chronic medical condition potentially affecting sleep (e.g., pain syndromes); 3) they were taking medication(s) or supplements potentially impacting mood or sleep (i.e., melatonin); 4) they were non-compliant with the prescribed sleep manipulation; 5) if teens reported typical sleep of less than 6.5 hours per night OR 9.5 hours or more per night on the phone screener, and 6) if adolescents were receiving or seeking treatment services (therapy or pharmacotherapy) for a current psychiatric disorder/problems and/or endorsed current suicidal ideation.

The CONSORT diagram for the current study is presented in Figure 1. A total of 261 people expressed interest in the study. A total of 194 were either not interested after gaining additional information (*n* = 81) or were unable to be contacted for additional information after 3 phone calls (*n* = 90). Twenty-three people interested in the study were found to be ineligible based on a brief phone screener. The most common reasons for ineligibility were concern of a sleep disorder (i.e., sleep disordered breathing), or seeking psychological/sleep treatment. A total of 67 people were invited to participate in the study. Fifteen people either canceled or did not show up to the initial appointment and an additional 6 participants were deemed ineligible based on results on the initial evaluation assessment. A total of 36 adolescents were enrolled in the current study, but six participants withdrew due to conflicts between their schedule and study participation. Thus, the final sample included 30 adolescents.

Randomization of Participants

A pre-randomized list of ID numbers was established for randomization of participants to one of the two sleep conditions. Research assistants were blinded to the planned randomization order and ID numbers. As described below, adherence to the assigned condition was checked at the end of the experimental sleep period, prior to the in-lab emotional assessment. Notably, of the first five participants assigned to the SE condition, all five were non-adherent with study procedures (i.e., they did not extend their sleep), which resulted in a larger proportion of participants being randomized to the SE group (n = 20) relative to the TS group (n = 10). Within the SE group, a total of 10 participants were unable to successfully extend their sleep. Thus, a total of 10 TS and 10 SE subjects completed the current study.

Of the 20 participants that completed all parts of the study, 12 (60%) were female, and the average age was 15.75 years (*SD* = 1.14; range 14-17). Of note, no 13 year olds were enrolled, likely due to the focus on recruiting from high schools, rather than middle schools. On average, participants had 4.8 (SD = 1.57) people in the household, and the majority (70%) of participants' parents were married to the other parent. Forty-five percent of mothers and 60% of fathers had at least a college degree.

In terms of race, 40% of children in the current sample identified as Caucasian. The sample was representative of the Houston area, as 20% identified as African American, and 10% identified as Asian. Thirty percent of the current sample identified as Hispanic/Latino. With regard to socioeconomic status, the majority of participants had an annual household income above 100K (55%). Most participants were in early to mid puberty according to the Pubertal Development Scale (*M* = 3.56, *SD* = .58). TS and SE groups did not differ on any demographic or pubertal variables (See Table 1).

Baseline Measures

Duke Structured Interview for Sleep Disorders (DSISD; Edinger et al., 2009). This semi-structured sleep interview was conducted individually with adolescents to assess diagnostic criteria for all ICSD-2 sleep disorders. Although this measure was originally designed to assess for sleep disorders in adults, it has also been used in adolescents (Talbot et al., 2010).

Parent report.

Demographic information. Demographic information was collected from parents at the initial evaluation, including race/ethnicity, date of birth, age, and sex of the participant, parental race/ethnicity, parent ages, parental marital status, parent educational achievement, total family income, and total number of people in the household. Additionally, parents reported on any current and past medications prescribed to the participant, any current and previous medical and psychiatric diagnoses for the participant, and family history of psychiatric diagnoses.

Child Behavior Checklist for Ages 6-18 (CBCL; Achenbach, 1991). The CBCL is a 113-item, standardized, parent-reported scale assessing a broad range of behavioral problems, and social and academic functioning. Parents rated their children's behavior "now or within the past 6 months" on a 3-point Likert scale (0 = not true, 1 = somewhat or sometimes true, and 2 = very true or often true) on prompts like: "acts too young for his/her age" and "suspicious." Broad and narrow-band syndrome scales and DSM-oriented scales can be derived from these items. The CBCL is one of the most extensively tested rating scales available, possesses excellent psychometrics (Achenbach, 1991), and has high internal consistency (Achenbach, 1991; Albores-Gallo et al., 2006).

Sleep Disorders Inventory for Students – Adolescence (SDIS-A; Luginbuehl et al., 2003; Luginbuehl, Bradley-Klug, Ferron, Anderson, & Benbadis, 2008). This 30 item parent-reported measure of sleep related problems is a reliable and valid for measure for assessing sleep in adolescents between 11 to 18 years of age (Luginbuehl et al., 2008). This measure produces five subscales assessing obstructive sleep apnea (OSAS), narcolepsy, periodic limb movement disorder (PLMD), delayed sleep phase disorder (DSPS) and excessive daytime sleepiness (EDS). Reliability estimates for this measure are excellent (α = .92; Luginbuehl et al., 2008). Only the total score from the SIDS-A was used in the current study.

Child Report.

Self-Reported Pubertal Scale (Carskadon & Acebo, 1993). Adapted from a previous puberty rating scale (Petersen, Crockett, Richards, & Boxer, 1988), the present pubertal self-rating scale was designed to be used without pictorial representations of pubertal maturation, and scoring of pubertal development maps onto the Tanner rating scale (Marshall & Tanner, 1969, 1970). The self-reported pubertal scale assesses both general and gender-specific indicators of development and has excellent validity estimates. As pubertal maturation has been shown to impact sleep (Jenni et al., 2005), this scale was used to assess group differences on pubertal maturation. In the current study internal consistency was observed to be poor for boys (α =.57) and good for girls (α =.88); this discrepancy across sex was likely due to the larger number of female participants.

Technology use questionnaire. This measure was developed for the current study to assess for typical levels of technology use that could affect comfort during the lab-based interaction (i.e., video-chat) tasks and the computer game. As youth with more computer and video-chat experience may have felt more comfortable during the lab-based tasks, frequencies of these behaviors were assessed so that differences in technology familiarity could be examined as potential covariates. Please see Appendix A for a full version of this questionnaire. Reliability of this measure in the current study was poor (α = .38) likely due to the small sample size and limited number of items on this scale. Further, this scale likely assessed items that do not correlate, thus contributing to low internal consistency. For example, adolescents who watch a lot of TV may or may not be frequently awoken by text messages.

Revised Child Anxiety and Depression Scale (RCADS; Chorpita, Yim, Moffitt, Umemoto, & Francis, 2000). This scale yields a total score and subscales corresponding to specific DSM-IV internalizing disorders. The RCADS was used to assess specific symptoms of anxiety and depression, including social anxiety. The RCADS produces scaled scores for major depressive disorder, generalized anxiety disorder, obsessive compulsive disorder, panic disorder, separation anxiety disorder, as well as a total anxiety & depression score. The measure has high internal consistently and high convergent/divergent validity in discriminating between clinical and non-clinical children between 8 to 18 years of age (Ebesutani et al., 2010). In the current study, internal consistency of the RCADS was excellent (α =.94).

Profile of Mood States-Adolescents/BRUMS (POMS-A/ BRUMS; Brandt et al., 2016; Terry et al., 1999). The POMS-A (also known as the BRUMS) is a well-validated, 24-item, abbreviated self-report measure based on the original Profile of Mood States (McNair, Lorr, & Droppleman, 1971) questionnaire. The abbreviated version maps on to the original six sub-scales: Tension/Anxiety, Depression/Dejection, Anger/Hostility, Energy/Activity, Fatigue/Vigor, and Confusion/Bewilderment. This measure also yields a Total Mood Disturbance score (i.e., negative emotion). Participants were asked to report on their mood "over the past 3 days, including today", using a 5-point scale ranging from 0 ("Not at all") to 4 ("Extremely"). Items were summed to create the six total subscale scores, and the Mood Disturbance Score was calculated by subtracting Vigor scores from the sum of all remaining subscales. The POMS-A was administered at the initial appointment and after Phase 2. The

POMS-A has been shown to be valid and reliable in adolescent samples (Lane, Whyte, Terry, & Nevill, 2005; Terry et al., 1999). In the current study, baseline reliability for the vigor (α =.76), total mood disturbance (α =.82) subscales were acceptable. Following Phase 2, reliability on the POMS vigor scale (α =.64) was poor, and reliability of the total mood disturbance scale (α =.82) was good.

Epworth Sleepiness Scale (ESS; Johns, 1991). This self-report questionnaire was used to assess each participant's general level of daytime sleepiness at the baseline appointment and after Phase 2. Participants were asked to indicate their "chance of dozing" in eight different scenarios such as "sitting and reading," "watching TV," and "in a car, while stopped for a few minutes in the traffic" on a scale of 0-3, with 0 indicating "would never doze" and 3 indicating "high chance of dozing." The ESS has been shown to have high internal consistency and reasonable test-retest reliability (Johns, 1991). Reliability in the current study was acceptable at baseline (α =.75) and following Phase 2 (α =.81).

Children's Morningness-Eveningness Preferences (CMEP) Scale (Carskadon, Vieira, & Acebo, 1993). Adapted from the Horne-Ostberg Morningness-Eveningness Questionnaire (MEQ; Horne & Ostberg, 1976), this 10-item scale yields a total score ranging from 10 to 43 and has good reliability and validity (Kim, Dueker, Hasher, & Goldstein, 2002). Cutoff scores based on the two outer quartiles of the CMEP are 27 or lower for evening-type classification and 32 or higher for morning-type classification. Reliability in the current sample was acceptable (α =.79).

Distress Tolerance Scale (DTS; Simons & Gaher, 2005). Participants self-reported on baseline ability to experience and withstand distressing psychological states on 15 items, each rated on a 5-point Likert-type scale (1 strongly agree to 5 strongly disagree; Simons &

Gaher, 2005). The DTS assesses four types of emotional distress, including perceived ability to tolerate emotional distress, subjective appraisal of distress, attention being absorbed by negative emotions, and regulation efforts to alleviate distress (Simons & Gaher, 2005). Higher scores are indicative of greater levels of distress tolerance (Simons & Gaher, 2005). The DTS has demonstrated high levels of internal consistency in previous adolescent samples (α = .86; Zvolensky, Marshall, Johnson, & Hogan, 2009). In the current study reliability for the total scale (α =.53) was poor.

At Home Sleep Assessment

Sleep diary. Participants were asked to keep a sleep diary using a provided online form (administered via the online survey system *Qualtrics)* during the 7 baseline nights and the 5 nights of sleep manipulation (12-nights total). Specifically, they were asked to report their bedtime, wakeup time, estimated sleep onset latency (time in bed before falling asleep), number of awakenings at night, total sleep time, and any unusual occurrences during the night. Additionally, all participants were asked to report on the quality of their sleep, frequency and duration of naps each day, exercise, any intake of caffeine, alcohol, or medications, and specific activities one hour prior to bedtime including technology use.

Actigraphy. Each participant wore a Micro Sleepwatch (Ambulatory Monitoring Inc.) for 12 consecutive nights following the baseline assessment: 7 nights of typical sleep and 5 nights of manipulated sleep. Actigraphy data (including event markers) were used to determine bedtime and wake-up time for scoring. Computerized scoring using the Sadeh algorithm was used as this has been validated for use in adolescent samples (Sadeh, Sharkey, & Carskadon, 1994). Actigraphy variables collected included total sleep time (TST - total time spent asleep each night), sleep onset latency (SOL - number of minutes it took each participant to fall asleep after getting into bed), wake after sleep onset (WASO - the number of minutes each participant spent awake after initially falling asleep), sleep efficiency (the total minutes spent asleep divided by the total minutes spent in bed), bedtime, and wake-up time. To demark bedtime and wake-up time, participants were instructed to push a button (event marker) on the actigraph at bedtime and at their wake-up time. This button marks the data with a time stamp. For bedtime, participants were instructed to push the button when they began to actively try to fall asleep (i.e., when they turn out the lights). At wake-up time, participants were instructed to push the button once they get out of bed (i.e., when their feet "hit the floor").

Daily mood questionnaire. During the 7 nights of baseline sleep (Phase 1) and the 5 nights of sleep manipulation (Phase 2), participants were asked to respond to several mood related questions on a 10-point likert-type scale ranging from 1 (not at all) to 10 (extremely). This short 7-item measure assessed nervousness/worries, sadness, anger, fatigue, amusement, warmth, and happiness. Negative mood variables (nervous/worried, angry, sad) and positive mood variables (amusement, warmth, happiness) were summed to calculate daily scores of negative and positive mood, respectively. The questionnaire was administered via the online survey system *Qualtrics*. Participants were sent a link each evening at 7:00pm, and were asked to complete the survey after entering their ID number. Please see Appendix B for a copy of the daily mood questionnaire. Reliability of the negative mood scale was good during Phase 1 (α =.86) and acceptable during Phase 2 (α =.77), while the reliability of the positive mood scale was excellent across both Phase 1 (α =.97) and Phase 2 (α =.96).

Experimental Assessment Measures

Subjective emotional reactivity. The Self-Assessment Manikin (SAM) arousal and valence ratings (Bradley & Lang, 1994) were used to assess emotional reactivity during the in-lab experimental assessment tasks. Please see Appendix C and D for SAM ratings scales that were administered after each social interaction task and the computer game.

Linguistic Inquiry and Word Count (LIWC; Pennebaker et al., 2001). This computerized text analysis program was designed to categorize and quantify emotional language. The LIWC has been shown to have good validity in quantifying emotional responses (Kahn, Sheppes, & Sadeh, 2013). The LIWC also calculates total word count, words per sentence, "I" usage, and "we" usage, but only outputs of positive emotion frequency, negative emotion frequency and total word count were used in the present study.

Facial expression. Facial expressions was analyzed using FaceReader version 5.0 (Noldus Information Technology B. V., 2012), a commercially available program that uses algorithms to evaluate and classify facial images and videos, on frame-by-frame basis, into the following categories of basic emotions: happiness, sadness, anger, surprise, fear, disgust, and neutral (Ekman & Friesen, 1977). Additionally, the program also calculates emotional valence, which is a measure of overall positive vs. negative affect in the participant's emotional response.

The FaceReader program works by first finding the face using the Active Template Method. Next, it models the face by creating a virtual, super-imposed 3D Active Appearance Model featuring almost 500 unique marks of the face. Finally, FaceReader classifies the face by computing the intensity and probability of facial expressions for basic emotions. These variables reflect a measure of the magnitude of the emotion being shown from 0% (not at all) to 100% (perfect match). Within the program, there are four models to select from (general, children, east-asian, and elderly) allowing for appropriate model selection. Additionally, FaceReader accounts for individual characteristic facial expression that some people have by nature (sad, angry, etc.) through a 2 minute calibration procedure. Agreement rates of 90% with human analysis have been demonstrated (Chentsova-Dutton & Tsai, 2010). Only valence output measures (i.e., valence and variability in valence) from FaceReader from the computer game task were used in the present study, as FaceReader cannot be used when participants are engaged in speaking.

Emotion regulation goals/integrity check. After each in-lab social interaction, participants rated the degree of effort they put forth into each conversation (i.e., "How much effort did you put into this interaction?") on a 0-10 likert-type scale ranging from 0 = no effort, to 10 = extreme effort. Effort ratings for both interactions were evaluated to ensure at least moderate (i.e., 5 or greater) effort was endorsed during both tasks and to assess if effort increased from the first (naturalistic) to the second (manipulated) interaction task.
Finally, immediately prior to de-briefing, participants reported on the best and worst parts of the current study and the current study, as well as their understanding of the purpose of the current study. This questionnaire (see Appendix E) also included a single item assessing if participants believed the experimenters were honest (i.e., "Do you think the researchers were honest?" [yes/no]), and why/why not. The single dichotomous honesty item was assessed as a measure of "believability" of the manipulation task.

Procedures

Baseline assessment. After completing a brief phone screen (See Appendix F), potentially eligible participants were invited into the lab for an initial evaluation to confirm eligibility. Participants and their parent provided informed assent/consent following explanation of all aspects of the study with the exception of the specific purpose of the in-lab experimental assessment. Parents and adolescents were informed that the current study was interested in understanding how sleep impacts the way teens interact with computer technology rather than the true study objectives. This deception was necessary to reduce the possibility of subject-expectancy effects and/or demand characteristics during the in-lab assessment.

Following completion of the study, teens were debriefed about the actual study goals (i.e., to examine how sleep impacts aspects of emotion). All baseline assessments were completed during a 2-hour window in the evening (i.e., between 4:00pm to 6:00pm) on a weeknight to control for possible circadian effects on performance and affect ratings (POMS-A). The baseline assessment included signing of consent/assents forms and adolescents and their parents completed self-reported measures of sleep behaviors, circadian rhythm preference, mood, pubertal development, technology use, and psychological symptoms/behaviors. A structured interview was administered individually to teen participants in order to rule out the presence of sleep disorders.

Sleep monitoring and manipulation. The impact of SE on emotional reactivity, emotional language, and on social and frustration focused emotion regulation skill was tested using a between-groups experimental design. Following the initial assessment, adolescents wore an actigraph and completed sleep diaries for seven nights (Phase 1: baseline sleep week) always beginning on a Sunday evening. Phase 1 was required for all participants so that a "typical amount" of sleep could be established for participants randomized to the SE group. On the final Sunday of Phase 1, each participant's self-reported total sleep time, bedtime, sleep onset latency and waketime over the last 7 days were analyzed via their self-reported *Qualtrics* data. After assessing this information, the experimenter then informed the participant (and their parent) over the phone to which group they had been randomized. Adolescents then began Phase 2 (5 nights of sleep manipulation) after being randomized to one of two sleep conditions for five consecutive nights (Sun – Thurs): SE or TS. Participants in the SE group were asked to extend their sleep by 1 hour (60 minutes) on each of the five nights by going to bed earlier, whereas the TS group was instructed to continue sleeping normally. Self-reported data from *Qualtrics* was used to calculate the required extension time (in minutes) for participants randomized to SE. Further, a bedtime was recommended in the context of each SE participant's usual waketime for the following 5 nights of Phase 2.

Because previous research has suggested that youth asked to extend their sleep by one hour may only be successful in extending their sleep by about 30 minutes (Sadeh, Raviv, & Gruber, 2000), SE participants were asked to extend their sleep by 60 minutes, but only an extension of 30 minutes (on average) was required for participants to be considered adherent with study procedures. Those failing to meet this 30-minute extension criterion were excluded from the study. Sleep criteria for both Phases 1 and 2 were checked (based on actigraphy) prior to beginning the in-lab experimental assessment at the follow up appointment. As it was essential that each participant completed Phase 2 immediately prior to the in-lab experimental assessment, participants who rescheduled their in-lab assessment appointments were asked to re-complete the 12 days of actigraphy (both Phases 1 and 2).

In-lab experimental assessment. On the Friday immediately following Phase 2, between 4:00pm to 6:00pm, all participants completed the in-lab assessment that included self-reported reactivity measures (SAM arousal and valence ratings) administered throughout a computerized battery of tasks. All participants completed the assessment at the same time of day in order to control for possible diurnal effects on mood (Clark, Watson, & Leeka, 1989; Hasler, Mehl, Bootzin, & Vazire, 2008; Murray, Allen, & Trinder, 2002). The assessment battery included three computerized tasks administered in the same order: a) a naturalistic (un-manipulated) on-line social interaction task; b) a game designed to increase frustration and negative mood; and c) a second (manipulated) on-line social interaction task. All tasks were completed in the same observation room, in which each participant sat in front of a 22" computer monitor. The social interaction tasks included two different research staff confederates. In effort to standardize interactions across both groups, all confederates were female and aged slightly older than participants (i.e., early college aged-research assistant).

Self-reported SAM arousal/reactivity and mood ratings were collected after each interaction task and following the frustrating computer game. Frustration ratings were also collected after the computer game task and effort ratings for each conversation were collected after each interaction task (See Appendix C and D). Video monitoring was used throughout all tasks for post hoc coding of facial expressions and emotional language using FaceReader and LIWC programs, respectively.

At the start of the laboratory assessment, participants were informed that he or she would first be interacting with two peer research participants (who were actually confederates) on an iPad and then playing one computer game. The participant then interacted with one peer via a video-chat stream for 5 minutes. Similar to previous research examining social anxiety (Erath, Flanagan, & Bierman, 2007; Turner, Beidel, & Larkin, 1986), the participant was asked to get to know the other person as if they were a new neighbor or a new classmate. No additional instructions were provided. A confederate in another room in the lab interacted with the participant through a video-chat tablet interface (which was unknown to the participant). All confederates were trained to respond in a polite manner to help the participant keep the conversation going as appropriate, but while not being overly emotive or talkative (Please see Appendix G for confederate instructions). After data collection, FaceReader was used to examine the valence of emotional facial expressions and the variability in emotional facial expression valence during this interaction task.

As emotional expressiveness and valence displayed within conversations was expected to be significantly different across individuals, each participant completed two baseline calibration checks prior to the first social interaction task. First, a brief calibration check was completed to ensure all computer programs and system interfaces were working correctly. Participants then completed the 2 minute baseline task to account for individual characteristic facial expression that some people have by nature (sad, angry, etc.). This was followed by the non-manipulated social interaction task, the computer game, and the manipulated social interaction task.

Non-manipulated social interaction task. This task occurred after the participant entered the assessment room, was seated in front of the computer and following the two baseline calibration checks. During the non-manipulated social interaction task, the participant was instructed to get to know the other person (confederate) as if they were a new neighbor or a new classmate for 5 minutes. No additional instruction was provided. After this task, participants completed SAM arousal and valence rating scales, and a rating of the amount of effort the participant put into the conversation. LIWC scoring of their language was used to quantify emotional language (frequency of positive and negative emotional words and total word count).

Manipulated social interaction task. After the first social interaction task, a research assistant informed each participant that the person they were going to interact with next was running late because they couldn't find their cell phone. The following script was used as a guide:

> *We are going to have to make a slight change. You were going to interact with a different person next, but she is actually running late because she can't find her cell phone. She seemed very upset because she thinks she that she lost it and didn't back up any of her contacts or pictures. She said she needs some time to look for it. So while we're waiting for her we'll have you do the computerized game task. Does this sound OK?*

After the computerized game task (described below), each participant was told that the other participant (confederate) was ready to chat quickly, so that participants did not have time to cool down from the frustrating task before beginning the manipulated social interaction task. The participant was instructed to make the other person (confederate) feel better. The direction was given using the following statement as a guide:

> *The next person you're going to interact with is ready now and we need to get started since we're behind schedule. Again, try to get to know her as if she was a new neighbor or classmate. One thing though: she is pretty upset about losing her phone. We really appreciate her participating in this study, so would you please try your best to cheer her up when you talk with her?* (Ask for affirmative response from participant)

No other directions were given. All confederates in this task began the interaction by looking sad and providing the following backstory (as a guide with emphasis on conveying disappointment):

> *I'm sorry I'm late. I lost my Phone. I have been meaning to back up all the stuff on it but I never did and now all my pictures, videos, contacts, are gone! I can't believe how dumb I am. Plus my parents just bought the phone for me!*

For the remainder of the 5 minute interaction, the confederate responded to the participant in a polite and matter-of-fact manner, but minimized smiling or laughing. After this task, participants completed SAM arousal and valence rating scales, and a rating of the amount of effort the participant put into the conversation. LIWC was again used to quantify emotional language (frequency of positive and negative words and total word count) during this conversation.

Computer game. Following the first social interaction and after the participant was informed the other person (confederate) was late, participants completed a computer game. Participants were asked to play the Paced Auditory Serial Addition Task (PASAT-C; Lejuez, Kahler, & Brown, 2003). This computerized task required participants to sum numbers sequentially as they appear on the computer screen. Designed as a measure of distress tolerance, the PASAT-C was used in the current study to elicit frustration. The first round of the task is designed to assess each participant's performance and was used to determine the speed of following rounds (i.e., ensuring that the task is calibrated to each participant's skill level). The participant's persistence on the task was also recorded. Although this task was originally developed to measure information processing capacity (Gronwall, 1977), the PASAT-C is also used to evoke negative affect (Feldner, Leen-Feldner, Zvolensky, & Lejuez, 2006). To reduce social desirability effects, the research assistant informed all participants they could quit the task at any time and stepped out of the room during the task. Facial expression valence and variability in valence (assessed via FaceReader) collected during the computer game task were used to assess differences in facial expressive emotional reactivity across SE and TS groups.

Before beginning the task, all participants were instructed to do their best using the following script:

> *Now you're going to play that computer game I mentioned. Please do your best on this game as we keep track of who gets the highest scores. It seems like most teens*

that have played this game do really well, so it should be pretty easy, but even so, please try you absolute best.

After the PASAT-C, participants completed SAM arousal and valence rating scales. Participants were also asked to report on their level of frustration during the game on a likert scale ranging from 1 to 10 (1= not at all; 10 = extremely frustrating).

Debriefing. After all three tasks were completed, participants completed a post-study survey of the in-lab experimental assessment asking them to report on the suspected purpose of the study in addition to any other factors they believed the researchers might be assessing. Please see Appendix E for a complete copy of the questionnaire. Although the current study planned to exclude participant who guessed the true purpose of the experiment prior to full disclosure by the research assistant, no participants endorsed a suspicion that emotion was the true object of the experimental assessment. After completing the post-study survey, participants were informed that the current study was interested in the impact of sleep on emotions and social interactions, that their peer participants were actually confederates, and that the game was designed to be frustrating. Additionally, participants were informed that no one lost their cell phone. The purpose of hiding our true goal of examining emotions was explained and processed with each participant. All participants were given the option to withdrawal their data after debriefing, however no participant elected to withdrawal themselves from the study.

Compensation

Participants were compensated according to their level of adherence to the sleep manipulation requirements, responses to daily mood questions, and completion of the final study appointment. Participants could earn a total of $50 for full compliance in all aspects of the study. Thus, participants were informed that they could earn $2.50 per day for completing all aspects of the at home assessment ($20 total for all 12 days of complete actigraphy, sleep diary and daily mood questionnaire data, and sleep patterns consistent with group randomization [i.e., SE or TS]), and $30 for completing the final in-lab experimental assessment appointment (total of $50).

Analytic Plan

All data analyses were performed in SPSS version 23. After data collection, normality and linearity of all variables were examined. Missing data were analyzed using Little's Missing at Random (MAR) test to determine if data were missing *completely* at random.

Sleep manipulation check. After accounting for missing data, an ANOVA was used to compare SE and TS groups on actigraphy measured TST during the non-manipulated 7 nights of sleep to ensure baseline levels of sleep were not significantly different. Next, an ANCOVA, controlling for baseline TST was used to examine group differences during Phase 2 to ensure SE was successful. Significantly longer TST in the SE group relative to the TS group was expected in in the ANCOVA model only. No group differences were expected on the first ANOVA model examining Phase 1.

Second, ESS scores were examined to assess sleepiness across both groups before and after the at home sleep monitoring period (i.e., Phases 1 and 2). An ANOVA was used to compare SE ant TS groups on subjectively reported sleepiness on the ESS at the baseline assessment. Next, an ANCOVA, controlling for baseline ESS score was used to examine group differences on the ESS immediately following Phase 2 to assess for any changes in sleepiness as a result of the sleep manipulation. Significantly lower ESS scores in the SE group relative to the TS group were expected for the ANCOVA model only. No group differences were expected on the first ANOVA model examining baseline ESS scores.

Preliminary analyses. To assess for potential confounding variables to be used as covariates in models (below), a series of independent samples t-tests were conducted to compare groups on baseline measures of psychological symptoms (RCADS, CBCL), sleep (SDIS-A, ESS, CMEPS), and pubertal development. Independent samples t-tests were selected rather than a multivariate approach due to the small sample size. Sleep condition (i.e., SE, TS) was used as the between-subjects factor. Due to the small n, effect sizes and confidence intervals are reported along with p values for all models. For GLM models, $_{partial}\,\eta^2$ was used, as η and $_{partial}\,\eta^2$ are equivalent in univariate models (Levine & Hullett, 2002).

Aim 1. The first aim of the current study was to examine the effect of SE on subjectively assessed mood both within and between groups using: 1) pre- and post-sleep manipulation POMS-A scores and 2) daily measures of mood across the 12 days of sleep monitoring (i.e., 7 days of baseline sleep, 5 days of manipulated sleep). Two repeated measure mixed between-within generalized linear models (GLMs) were used to compare within-group changes on the mood disturbance and vigor subscales of the POMS-A, and to assess if these pre- to post- changes were significantly different across the SE and TS groups.

To assess daily changes in positive and negative mood, spaghetti plots were first examined for positive and negative mood across the 7 days of Phase 1 and the 5 days of Phase 2 (12 days total). Repeated-measure mixed between-within GLMs were used to assess changes in positive and negative mood. Sleep condition was entered as the between-subjects factor in both the positive and negative mood models. Mood scores were entered as the within subject factor.

Aim 2. The second aim of the current study was to assess the effect of SE on emotional reactivity across measures of subjective emotional reactivity (SAM arousal and valence ratings completed following the frustrating computer game), emotional language reactivity (total word count, positive and negative emotional language during the naturalistic social interaction task), and facial expression reactivity (expression valence and valence variability during the frustrating computer game task). All reactivity measures were examined using univariate ANOVAs due to the small sample size and lack of significant correlations between conceptually grouped measures (See Results). This approach resulted in eight separate models, with each individual reactivity measure entered as the dependent variable and group entered as the independent variable.

Aim 3. The third aim of the current study was to assess the impact of SE on emotion regulation in a social context, following a frustrating task. To measure subjectively reported emotion regulation, two repeated-measure GLMs were completed to assess changes in SAM arousal and SAM valence scores across the naturalistic and manipulated social interaction tasks. In each model, the social interaction (i.e., naturalistic social interaction, manipulated social interaction) entered as the within subject variable, and group was entered as the between-subject variable. To measure language-based emotion regulation skill, three repeated measure GLM models were completed to assess changes in LIWC scores of total word count, positive emotional language and negative emotional language across the naturalistic and manipulated social interaction tasks. Again, social interaction (i.e., naturalistic social interaction, manipulated social interaction) was entered as the within subject variable, and group was entered as the between subjects variable. Finally, to assess frustration based emotion regulation, one ANOVA was completed to compare SE and TS groups on PASAT-C task persistence (in seconds).

RESULTS

Missing Data

Missing data were analyzed using Little's Missing Completely at Random test, which supported the hypothesis of completely at random missing data ($\chi^2_{(60)}$= .000, p = 1.00), meaning there was no statistical relation between missing and observed variables. To account for missing data, Expectation Maximization imputation was used (Peugh & Enders, 2004), which involves both an expectation step and a maximization step. In the expectation step, missing values are imputed using a regression imputation, followed by the maximization step estimating the covariance matrix and mean vector. These steps continue iteratively until differences between covariance matrices from ongoing maximization steps differ by only a trivial amount.

Tests of normality, linearity, and homoscedasticity of all variables were examined. There was evidence of a non-normal distribution on the CBCL internalizing problems scale (skew = -.358, *SE* = .512, kurtosis = 2.55, *SE* = .992), for negative emotional language in the manipulated social interaction task (skew = 1.08, *SE* = .512, kurtosis = 2.59, *SE* = .992), for positive emotional language in manipulated social interaction task (skew = 1.22, *SE* = .512, kurtosis = 2.07, *SE* = .999), and for SAM valence ratings from the naturalistic social interaction task (skew = 2.00, *SE* = .512, kurtosis = 5.48, *SE* = .999). However, examination of specific outliers (i.e., no outliers +/-3.5SD from the mean; Tabachnick & Fidell, 2000) and individual normality indices (i.e., Skew > 3; Kurtosis >10; Kline, 2015) revealed data were normally distributed.

Comparisons on Baseline Variables

When TS and SE groups were compared on baseline measures of psychological symptoms (RCADS, CBCL, DTS), sleep (SIDS-A, ESS, CMEPS), technology use, and daily affect (POMS), no group differences were observed. The groups were significantly different when summer participation was examined ($\chi^2_{(1)}$= 6.667, *p* = .010), with no SE participants running over the summer months. When TST for participants enrolled in the summer versus school year were compared, there was a significant differences in baseline week TST (*t* = -3.18, *p* = .005) with participants who ran during the summer sleeping significantly longer (Summer TST *M* = 482.28, *SD* = 36.04) than participant who ran during the school year (School-year TST *M* = 402.54, *SD* = 51.62). Thus, summer participation was entered as a covariate in all remaining analyses.

To ensure the SE participants included in the current study were a representative sample, these adolescents were compared to non-compliant participants randomized to SE who were not included in the study (i.e., those who failed to extend their sleep) on baseline and demographic measures. On measures of psychological symptoms (RCADS, CBCL, DTS), included SE participants had higher scores on the RCADS total Anxiety & Depression scale (*t* = -2.61, *p* = .018) than non-compliant SE adolescents (See Table 2). On baseline measures of sleep (SIDS-A, ESS, CMEPS), technology use, and daily affect (POMS), no group differences were observed. Compliant and non-compliant SE groups also did not differ on age, pubertal status, gender, marital status, ethnicity/race, total family income, parent education or total number of family members in the home (See Table 3).

Sleep manipulation check. When SE and TS groups were compared on actigraphy-derived total sleep time (TST) during Phase 1, differences across TS (*M* = 453.97, *SD* =

63.85) and SE (*M* = 390.98, *SD* = 33.03) groups were non-significant (*F* = 1.769, *p* = .201). When the groups were compared on TST during the Phase 2, participants in the SE group (*M* = 449.41, *SD* = 47.22) slept significantly longer than did participants in the TS group (*M* = 415.17, *SD* = 41.35; *F* = 9.643, *p* = .007).

When SE and TS groups were compared on ESS scores at the baseline appointment, differences across the TS (*M* = 6.12, *SE* = 2.42) and SE (*M* = 9, *SD* = 5.09) groups were non-significant (*F* = 1.15, *p* = .299). When groups were compared on ESS scores following Phase 2 at the second appointment, differences across TS (*M* = 7.40, *SE* = 3.80) and SE (*M* = 11.30, *SE* = 4.94) groups were also non-significant (*F* = .222, *p* = .644). Actigraphy and ESS sleep parameters for both groups and group differences are presented in Table 4.

Emotion regulation manipulation check. When effort scores following the social interaction tasks were examined, the SE group and the TS group both reported adequate levels of effort across both the naturalistic interaction task (SE: *M* = 7.20, *SD* =1.75; TS: *M* = 7.00, *SD* =2.26) and the manipulated interaction task (SE: *M* = 7.60, *SD* =2.31; TS: *M* = 7.70, *SD* =2.00). No group differences were found for the naturalistic social interaction task (*F* = .124, *p* = .729, $_{partial}\eta^2$ = .007), or the manipulated social interaction task (controlling for effort in the naturalistic task; *F* = .077, *p* = .786, $_{partial}\eta^2$ = .005). Further, there was no significant interaction between effort across the interactions tasks and group (*F* = .115, *p* = .698, $_{partial}\eta^2$ = .009).

With regard to believability of the deception used in the current study, immediately prior to debriefing, 100% of participants in both groups reported they believed the researchers were honest throughout the experiment.

Correlations

Bivariate correlations between POMS-A scales at baseline, and after Phase 2, as well as weekly negative and positive mood for both Phases 1 and 2 are presented in Table 5. Correlations across emotional reactivity measures (i.e., subjective emotional reactivity, language emotional reactivity and emotional facial expression) are presented in Table 6. Lastly, bivariate correlations for variables included in emotion regulation (i.e., SAM arousal and valence ratings across both interactions, emotional language across both interactions, persistence on the frustrating computer game) models are presented in Table 7.

Effects of Sleep on Subjectively Assessed Mood

Upon examination of spaghetti plots for both daily positive and daily negative mood (see Figures 2 and 3), no observable (linear, quadratic or cubic) trends were noted, and thus weekly (i.e., Phase 1 and Phase 2) averages were used rather than daily mood scores. Averages from Phase 1 and Phase 2 for positive and negative emotion were entered into two repeated measure GLM models (i.e., 2 models). Two repeated measure GLM models were also completed to examine changes in negative and positive POMS scales (i.e., 2 models), between the SE and TS groups across the two phases. For both POMS models, there was no phase x group interaction, nor was there a main effect of phase, or a main effect of group. All effect sizes were observed to be small (See Table 8).

For positive mood and negative mood models across Phases 1 and 2 of the in-home monitoring period, there were no within-subject phase x group significant interactions, nor were main effects of phase or group detected (See Table 8). Still, a medium effect size was detected for the group x phase interaction of positive mood ($_{partial}\eta^2 = 0.05$; 90% CI [.00, .25]). To better understand the nature of this effect (despite a lack of statistical significance), a post hoc paired sample t-test was completed. Results revealed a medium effect of a decrease in positive emotion within the SE group from Phase 1 to Phase 2. There was also a medium to large effect of Phase for negative emotion ($_{partial}\,\eta^2$ = 0.08; 90% CI [.00, .30]), suggesting negative emotion increased (non-significantly) in both groups on average from Phase 1 to Phase 2 (See Figure 4).

Effect of Sleep on Emotional Reactivity

To assess emotional reactivity, eight individual ANCOVAs (controlling for summer participation) were completed assessing subjectively reported emotional reactivity following the frustrating computer game (i.e., SAM arousal, SAM valence, frustration rating), objectively assessed emotional facial expression during the frustrating computer game (i.e., FaceReader expression valence and valence variability), and emotional language during the non-manipulated social interaction task (i.e., total word count, positive emotional language, negative emotional language). In all models, group status was entered as the predictor.

In ANCOVA models examining subjective emotional reactivity during the frustrating computer game, there were no significant group differences in SAM arousal, SAM valence, or frustration ratings collected after the frustrating computer game task. Further, no medium or large effect sizes (evaluated using Cohen's d [M_1-M_2/SD pooled]) were observed for these models (See Table 9).

In ANCOVA models examining emotional reactivity via emotional facial expression, the group difference for valence in facial expressions approached significance (F = 3.79, p = .069) and a large effect size was observed (*Cohen's d* = .871; CI [-.05, 1.79]). The groups did not significantly differ on variability of facial expression valence; however a medium effect size was observed (*Cohen's d* = .535; CI [-.36, 1.43]) with the SE group showing more negative facial expression valence and higher levels of facial expression variability than the TS group (See Table 9).

In ANCOVA models examining emotional language variables (i.e., total word count, positive emotional language, and negative emotional language) during the non-manipulated interaction task, there were no significant differences across the SE and TS groups for all three models, and no medium or large effect sizes were observed (See Table 9).

Effect of Sleep on Emotion Regulation

To assess emotion regulation, five individual repeated-measure GLM models assessing change in subjectively reported emotion (i.e., SAM valence and SAM Arousal ratings), and change in emotional language (i.e., total word count, positive emotional language, negative emotional language) across the non-manipulated and manipulated social interaction tasks were completed. In GLMs assessing subjectively reported emotion regulation, groups did not significantly differ across the tasks in terms of either valence or arousal ratings. However, when examining effect sizes for SAM arousal ratings, there was a large main effect size for time (${}_{partial}\,\eta^2$ = 0.14; 90% CI [.00, .37]), and a medium effect size of group (${}_{partial}\,\eta^2$ = 0.05; 90% CI [.00, .26]). Post hoc paired t-tests examining SAM arousal changes within groups revealed arousal ratings increased for the SE group, based on a medium effect size (See Figure 5). There was also a medium to large effect size for the group x time interaction for SAM valence ratings (${}_{partial}\,\eta^2$ = 0.06; 90% CI [.00, .28]). Post hoc paired t-tests examining SAM valence changes within each group revealed valence increased across interactions for the SE group based on a medium effect (See Figure 5). Results are presented in Table 10.

In models assessing emotional language regulation, LIWC assessed total word count, positive emotional language, and negative emotional language from both interaction tasks were entered into three repeated measure GLMs. There were no statistically significant interactions or main effects of group or time across all three models (See Table 10), however a medium to large effect size of a group x time interaction was observed for total word count ($_{partial}\,\eta^2$= 0.10; 90% CI [.00, .33]). Post hoc paired sample t-tests examining word count changes within each group revealed total word count increased during the manipulated interaction relative to the non-manipulated interaction for SE participants based on a medium effect size (See Figure 6).

Finally, one ANCOVA model was used to examine group differences on PASAT persistence (in seconds). A significant group difference was not observed, nor was there a medium to large effect size noted (See Table 10). A post hoc ANCOVA (controlling for summer participation) comparing SE ant TS groups on PASAT score (i.e., items correct) revealed that the groups did not differ on PASAT performance (F = .282, p = .603).

DISCUSSION

The current study is among the first to examine the impact of SE on emotion-based outcomes, including social emotion, in healthy teens. This research is critically needed in light of the fact that insufficient sleep predicts psychological problems including anxiety and depression (Babson, Trainor, Feldner, & Blumenthal, 2010; Caldwell, Jr., Caldwell, Brown, & Smith, 2004; Gregory, Caspi, et al., 2005; Gregory, Eley, O'Connor, & Plomin, 2004; Gregory & O'Connor, 2002; Rose, Manser, & Ware, 2008; Sagaspe et al., 2006), and inadequate sleep is highly prevalent among teens (Owens et al., 2016). Among adolescents in the United States, approximately 80% do not get enough sleep, particularly on weekdays

(NSF, 2006). Further, approximately 10% of adolescents experience problems falling asleep (Morrison et al., 1992). Indeed, in the current sample, adolescents averaged 7.2 hours of sleep per night during the Phase 1 baseline week; nearly 2 hours less than the current 9-10 hour recommendations from the National Sleep Foundation (NSF, 2015) and American Academy of Sleep Medicine (AASM; Paruthi et al., 2016). Further, due to poor compliance rates in the current study, all planned analyses were underpowered to detect statistically significant effects. For this reason, analyses largely focused on effect sizes where medium to large effect sizes were interpreted as meaningful. However, it should be noted that most confidence intervals contained zero, underscoring the inadequate sample size in the current study. Thus, replication of all findings is imperative for future research.

Sleep Manipulation

Despite problems encountered implementing SE in the current study, our experimental sleep manipulation did yield a significant increase in total sleep time within the SE group, relative to teens' typical sleep. Further, the SE group slept just over 30 minutes more on average per night than the TS group during Phase 2 and there was no significant increase in wake after sleep onset, as observed in prior SE studies (Sadeh et al., 2003). This difference may be explained by chronic insufficient sleep among most adolescents throughout the week, including the high level of sleep restriction across weekdays, and attempted recovery sleep on weekends (Touitou, 2013).

Notably, however, subjectively reported sleepiness scores did not change across the two groups following the sleep manipulation. Although sleepiness was expected to improve with the sleep manipulation, it is possible that sleepiness associated with the relative chronic sleep deprivation of adolescents in this sample (i.e., 7.2 hours/night average during Phase 1) may not have been adequately alleviated by 5 nights of 30 additional minutes of sleep. As previous experimental research in teenage samples has primarily used sleep deprivation/restriction paradigms to examine the impact of sleep on emotion (Baum et al., 2014; Talbot et al., 2010), the use of a sleep extension paradigm in the current study is novel. However, results for daytime tiredness suggest that the chronic state of sleep deprivation under which teens often function may not allow them to benefit fully from only an additional 30 minutes of sleep per night.

Effect of Sleep Extension on Alterations in Mood

When changes in negative and positive mood (via the POMS) were examined before Phase 1 and after Phase 2, subjectively reported negative and positive mood did not change across the two time points or across the two groups, and no significant interactions were observed. Additionally, there were no moderate to large effect sizes observed for these comparisons. This finding was surprising in the context of prior studies that have consistently observed decreased state levels of positive affect and mood in adolescents and adults (Baum et al., 2014; Dagys et al., 2012; Franzen et al., 2008; McMakin et al., 2016; Paterson et al., 2011; Talbot et al., 2010) and increased state levels of negative affect and mood in adolescents only (Baum et al., 2014; McMakin et al., 2016; Paterson et al., 2011) following sleep deprivation/restriction.

However, it is important to note that many of these prior studies utilized one or more nights of total sleep deprivation (Dagys et al., 2012; Franzen et al., 2008; Paterson et al., 2011), and those that used sleep restriction utilized much higher doses of sleep restriction relative to the sleep alterations used in the current study (Baum et al., 2014; McMakin et al., 2016; Talbot et al., 2010). For example, McMakin and colleagues (2016) used a 4 hour 2-

night restricted condition and a 10 hour 2-night rested condition, while Talbot and colleagues (2010) utilized two restriction nights of 6.2 hours and 2 hours, and two at home rested nights of 7-8 hours of sleep per night. Further, Baum and colleagues (2014) utilized a 5-night 6 hour restricted condition, relative to a 5-night 10 hour well-rested condition.

Considering the wide range of sleep restriction dosages used, results from prior research are likely capturing the effects of acute sleep deprivation among adolescents who are *already* chronically sleep deprived. As no changes in mood were observed in the current study after an approximately 30 minute increase in sleep for 5 nights (for a total of 2.5 hours more of sleep across the week), findings may suggest that mild increases in sleep are inadequate for alleviating all of the emotional effects of a chronic sleep debt in healthy adolescents. Thus, while informative, sleep restriction paradigms provide limited information about the minimal amount of sleep most teens need for healthy emotional functioning.

It is also important to consider the measurement and data collection protocols used in previous studies in order to best understand results from the current study. In general, studies have used different measurement frequencies of mood and affect, including assessment of negative mood at a single time point following 5 nights of sleep restriction (e.g., Baum et al., 2014), and periodic assessments of self-reported affect across a night of sleep restriction (e.g., McMakin et al., 2016). Both of these prior approaches differ from the approach of the current study where mood was assessed before and after a 2-week sleep manipulation. Furthermore, the current study sought to minimize potential bias in emotional responses through the use of deception regarding the specific goals of the current study (i.e., participants were told experimenters were interested in sleep and technology use). These methodological differences across studies may have contributed to the null findings observed in the current study, however additional research is needed to further explore the dose response of mood to changes in sleep among healthy adolescents.

Impact of Sleep Extension on Daily Mood

When daily mood scores were averaged over each sleep phase (i.e., Phase 1: 7 days of baseline sleep, Phase 2: 5 days of manipulated sleep), the patterns of both positive and negative mood changes were surprising. With regard to positive mood, it was anticipated that positive mood would increase for SE participants, consistent with research showing positive mood decreases among sleep deprived individuals relative to well rested controls (Franzen et al., 2008). However, upon examination of the means and effect sizes of positive mood across groups, participants in the SE group showed a (non-significant) decrease in their average positive mood, while there was no change observed in the TS group. With regard to daily negative mood, a medium to large main effect of time was observed, suggesting increased negative mood in both groups across study Phases.

Findings for both positive and negative mood were surprising, as subjective ratings of frustration and self-reported negative mood have been found to increase following sleep deprivation (Paterson et al., 2011; Vasile et al., 2013) or acute nap deprivation in young children (Berger et al., 2012). Increased positive mood has also been shown to decrease following sleep deprivation/restriction (Baum et al., 2014; Dagys et al., 2012; Franzen et al., 2008; McMakin et al., 2016; Paterson et al., 2011; Talbot et al., 2010). As much of the prior research has examined changes in negative mood at one time point immediately following sleep loss (e.g., morning after night of sleep deprivation, immediately following nap deprivation; Paterson et al., 2011; Vasile et al., 2013), or at several points across sleep restriction in the lab (McMakin et al., 2016), these studies may in fact be measuring emotion or stress response as defined by Gross, rather than mood.

Gross' conceptual model of affect stipulates that *mood* may be less sensitive to specific environmental stimuli, longer lasting, and generally more diffuse relative to the emotion and the acute stress response components of affect (Gross, 2015b). In contrast to prior measurements of mood, the current study utilized a cumulative measure of daily positive and negative mood, aggregated across both a baseline and manipulated week of sleep (i.e., Phase 1 and Phase 2). The aggregation of mood scores over several days in the current study may be more closely representative of the longer lasting, more diffuse, latent concept of *mood*, relative to the one time self-report measures of mood utilized in prior studies.

The timing of mood assessment may have also impacted negative mood findings of the current study. As daily mood was only assessed each evening in the current study, mood measurement may have captured the typical diurnal pattern of mood (i.e., decline) over the day (Clark et al., 1989; Hasler et al., 2008; Murray et al., 2002), rather than the impact of additional sleep on mood. This potential explanation is bolstered by findings that sleepiness among SE participants did not improve following Phase 2. Together, findings suggest that all participants remained sleep deprived throughout the study and thus both SE and TS groups were subject to the typical increase in negative mood across the day.

Further, qualitative data collected at the close of the present study from participants who completed or who dropped out of the study suggests that some adolescents (n = 3) experienced participation burden related to the daily completion of sleep diary and mood measures (e.g., three participants reported the hardest part of the study was: "Forgetting to answer the A.M. and P.M. questions", "Filling out the surveys every night and morning...", and "The surveys were a bit lengthy, and I often forgot to fill them out."). Thus, the increase in negative mood observed across both groups may be related to fitting numerous activities (i.e., homework, sports, etc.) into the evening, in addition to completing the nightly emotion measures on the computer as part of participation. Further, the decrease in positive mood observed in the SE group may also be related to the pressure of additional time constraints. Specifically, as SE participants were asked to condense their evening activities into a shorter period in order to advance their bedtime and extend their sleep, their evening schedules and activities (e.g., extracurricular activities, homework, socializing with peers, videogames/TV/texting) were likely more rushed and negatively impacted during Phase 2 of participation, relative to participants in the TS group. Future research should work to explore the association between mood and sleep, while accounting for the time lag between sleep and mood-based assessments and the additional burden that daily measures and sleep protocols may place on teenage participants.

Emotional Reactivity Findings

Emotional reactivity within the naturalistic interaction task. When emotional reactivity language variables were examined, there were no group differences and no medium or large effect sizes across any language reactivity measures (i.e., total word count, positive emotional language, negative emotional language). In the one study examining emotional language before and after sleep deprivation, McGlinchey and colleagues (2011) observed that positive emotion decreased across two verbal interviews with healthy teens (administered before and after a night of sleep restriction), in which participants answered a standard series of questions administered by the researcher (McGlinchey et al., 2011).

Further, no changes in negative emotional language were observed following sleep restriction (McGlinchey et al., 2011). As the language analyzed in the current study was conversation based, rather than responses to interview questions, it is possible discrepant findings across studies may be related to the interaction format. For example, participants in the current study may have modulated their language more due to concern about speaking with a strange peer compared to an experimenter. Social pressure in teens may be particularly salient due to the increased interest in peer connection and fear of social rejection during this developmental period (Brown, 2004; Furman, 2002; O'Brien & Bierman, 1988; Silvers et al., 2012; Steinberg & Morris, 2001).

Further, it is important to note that McGlinchey and colleagues (2011) examined language-based emotional reactivity following a relatively potent dose of sleep restriction (i.e., 2 hours less sleep) relative to the current study where sleep was extended by only 30 minutes per night. Thus, findings from the current study likely reflect that, in the context of peer interactions, emotional language is not altered by the addition of 30 minutes of sleep over 5 nights when teens are otherwise sleep deprived. Thus, future research is needed to develop a more nuanced understanding of the typical levels of emotional language across a variety of interactions (i.e., private language, interview language, conversation language), people in a variety of roles (i.e., friend, stranger, experimenter), and at different levels of sleep/sleep debt as these factors may all affect adolescent language based emotional reactivity.

Emotional reactivity during the frustrating computer game. When objective emotional reactivity was examined during the frustrating computer game, participants who extended their sleep displayed more negative facial expression, and a higher level of variability in their facial expressions relative to participants who slept “normally” (based on large and medium effect sizes, respectively). Findings from the current study are consistent with the one prior study to use the Facial Expression Coding System (FACES; Kring & Sloan, 2007) among participants who were sleep deprived (Minkel et al., 2011). Specifically, when sleep deprived, adults were observed to have less overall expressiveness relative to well rested controls (Minkel et al., 2011). The unique nature of the frustration task used in the current study is also important to consider in the context of prior research. Frustrating situations, especially when encountered in private, often elicit an appropriately frustrated response. In the context of the current study, where PASAT performance was similar between the sleep groups, participants who slept more appeared to have greater ability to demonstrate their frustration, while participants who received “typical” amounts of (restricted) sleep may have exhibited an emotionally blunted response. These patterns may be similar to the “emotional blunting” seen among sleep deprived individuals in prior studies (McGlinchey et al., 2011; Minkel et al., 2011).

Although few studies have used FaceReader to assess facial expression in general, among psychologically-ill populations, one study found individuals with eating disorders (especially those with anorexia nervosa) demonstrated significantly more blunted facial expressions after watching a positive movie clip relative to healthy controls and those who had recovered from eating disorders (Leppanen et al., 2017). In the current study, emotional blunting among teens who are sleeping only 7.2 hours per night on average may have deleterious effects on social cooperation, social interest, social competence (Pasnau et al., 1968; Stein et al., 2001; Totterdell et al., 1994), peer relationships (Baldwin & Daugherty, 2004), and academic achievement (Wolfson & Carskadon, 2003). Emotional blunting may be particularly detrimental to fostering adaptive peer relationships and minimizing social rejection from peers, as emotional expression has been linked with social competence (Halberstadt et al., 2001). Further, there is evidence to suggest that individuals who display blunted emotional responses in social situations are judged more negatively by other people (Szczurek, Monin, & Gross, 2012). As social withdrawal and reduced social support are both risk factors of affective disorders (Lewinsohn et al., 1994), increased facial reactivity may be socially protective against affective risk, especially in the context of appropriately frustrating situations.

However, given the limited work in this area, additional research is needed to confirm findings of improvements in facial expressive emotional reactivity among individuals who have extended their sleep. Further, as other forms of reactivity (e.g., pupillary reactivity), have been shown to increase rather than decrease following sleep restriction (McMakin et al., 2016), collective findings suggest that individual measures of reactivity (i.e., pupillary response, facial expression, emotional language) function differently across restricted and extended sleep states and do not necessarily correlate with one another (Franzen et al., 2009).

Subjective emotional reactivity following the frustrating computer game. When subjectively reported emotional reactivity was examined, no significant group differences and no medium or large effect sizes were observed on measures of arousal or valence following the frustrating computer game. Although this finding was not consistent with study hypotheses and previous sleep restriction/deprivation findings linking inadequate sleep (Leotta et al., 1997; Talbot et al., 2010) with increased negative reactivity (Wagner et al., 2002), other studies have presented mixed and null findings (Leotta et al., 1997; Minkel et al., 2011; Reddy et al., 2016). Further, the small body of literature linking napping to increased positive emotional reactivity and decreased negative emotional reactivity across adults and young children (Berger et al., 2012; Gujar et al., 2010) were also inconsistent with null findings of subjective reactivity measures in the current study.

Methodological differences across studies may in part explain different outcomes, as a majority of studies utilized higher dosages of sleep loss relative to the 30 minute increase for 5 nights utilized in sleep in the present study. For example, Minkel and colleagues (2011) used one night of total sleep deprivation, Wagner and colleagues (2011) compared a 3 hour sleep restriction occurring early in the night to a 3 hour sleep restriction occurring later in the night, while other studies have utilized between 4-6 hours of sleep restriction (Leotta et al., 1997; Reddy et al., 2016; Talbot et al., 2010). In the one study to extend sleep in adults via a 90 minute nap (Gujar et al., 2010), emotional reactivity was also assessed immediately following the nap. As the present study utilized a smaller yet more gradual level of sleep extension, findings for subjective emotional reactivity likely reflect the insufficiency of the sleep manipulation used.

As emotional reactivity has been documented to remain stable across late childhood into early adulthood (Silvers et al., 2012), findings in the present study may also suggest that despite observed differences in objective facial expression emotional reactivity, adolescents across *both* groups were not aware of their emotional expression. This possibility, and it's potential link with chronic sleep loss, is particularly alarming given the deleterious effects of poor emotional awareness on peer relationships (Penza-Clyve & Zeman, 2002; Saarni, 1999) and risky behavior (Hessler & Katz, 2010) during adolescence. Given the wide range of experimental protocols, it is essential that future research work to explore both the dose response relationship between sleep and emotional reactivity and the discrepancy between objective and subjective measures of emotional reactivity among adolescents.

Impact of Sleep Extension on Emotion Regulation

Emotion regulation was in part examined by assessing the changes in subjectively reported arousal and mood across the two interaction tasks. Results indicated arousal levels increased after the second (manipulated) social interaction task in the SE group but not the TS group (based on large and medium effect sizes). This finding may reflect increased social engagement among SE participants in the context of the emotional goal of the interaction task (i.e., cheer the other person up). The lack of change in the TS group, despite the explicit goal of the task, may also reflect emotional blunting in youth who slept less. Again, this finding is consistent with prior observations of emotional blunting among sleep restricted and sleep deprived individuals (McGlinchey et al., 2011; Minkel et al., 2011). As effective emotional expression has been associated with increased social competency (Halberstadt et al., 2001), participants who extended their sleep by 30 minutes for 5 nights in the present study may have had a higher capacity to appropriately interact with and respond to their social environment. As the SE dosage of 30 minutes over 5 nights in the present study was a relatively minor change, findings may suggest that a small change in sleep could facilitate appropriate social reactivity/arousal in the context of a specific emotional goal.

In regard to subjective valence ratings following each interaction, ratings in the SE group became more positive following the manipulated interaction task compared to the non-manipulated interaction. Thus, consistent with hypotheses, subjective valence was more positive following an emotionally goal-directed interaction (i.e., cheer up the other participant) for adolescents who slept more relative to those who slept “normally”. This increase in valence seen among teens who extended their sleep suggests these adolescents were better able to up-regulate their own positive affect in line with their social goals (i.e., to improve the mood of the peer confederate) even after playing a frustrating computer game. This emotion regulation skill, especially after experiencing frustration, has meaningful implications for developing and maintaining positive social relationships, facilitating more effective coping with difficult situations, and for reducing affective risk. Given the chronic sleep deprivation experienced by adolescents in the U.S. (NSF, 2006), improvements in emotion regulation skill following only a 30 minutes adjustment in sleep sustained over a week further supports the extreme need to alter adolescent schedules and school start times, as this minor change in sleep may have a number of effects on emotional, social, and academic functioning.

Building on these findings, the total number of words used by the SE group increased across the two social interactions. Although the hypothesized increase in positive emotional language and decrease in negative emotional language across the groups and the social interaction tasks were not found, the increase in total word count within the SE group suggests that participants who extended their sleep were better able to exert more effort during the second interaction relative to adolescents who had received less sleep. Notably, this increased effort based on word use was present in the SE group despite the lack of group differences on subjectively reported effort across the two interactions. When considered in the context of typical day-to-day adolescent functioning, individuals who get more sleep may be more effective in directing their own behavior in the face of distress. For example, teens who sleep more may be better able to support a peer who is upset or persist with academic tasks, household chores, or other responsibilities irrespective of their own emotional circumstances.

Conversely, findings from the present study may also suggest that the current amount of sleep adolescents “typically” receive limits their ability to modulate their emotional responses in context-specific ways; this may further increase affective risk during this already risky developmental period. Although these results require replication in a larger sample, findings provide preliminary evidence that a small increase in sleep duration of just over 30 minutes across 5 days may contribute to adolescents’ ability to regulate their emotions and behavior even when presented with frustrating situations.

SE and TS groups did not differ on frustration tolerance (i.e., PASAT persistence in seconds), contrary to study hypotheses. This null finding is likely related to the low level of variability in PASAT persistence across the entire sample, as the majority of participants (n = 14; 70% of participants) used all 420 seconds of the allotted time on the PASAT. Low variability in persistence rates may in turn be related to information given with regard to this task (i.e., all participants were told the task should be quite easy for them). As participants across both groups were, in essence, sleep deprived, (e.g., demonstrated similar sleepiness scores), it is also possible that participants did not fully attend to the directions given by research assistants that they had the option to quit anytime (cf. Pilcher & Huffcutt, 1996; Van Dongen et al., 2003). It is also important to note that the groups did not differ in PASAT performance, suggesting that participants in both groups were equally engaged in the task. Thus, findings may reflect the task’s inability to elicit emotional reactivity that required regulation in this sample of adolescents.

Compliance with and Feasibility of Sleep Extension in Teens

Compliance problems, including follow through with appointments, and dropout rates in the current study were very high. Specifically, only 6% of invited teens completed the full study protocol, and only 50% of those randomized to the SE group were successful in extending their sleep by an average of 30 minutes. To better understand the nature and specific difficulties associated with non-compliance, youth who dropped out of/were non-compliant with the study were asked to fill out a qualitative measure in effort to understand the problems that interfered with study completion. All but one of the participants who completed the drop-out form was in the SE group. For participants unable to complete the SE condition, specific problems cited included homework (n = 4), sports (n = 2), social activities (n=2), and difficulty with falling asleep earlier (n = 1) as factors that interfered with their ability to extend their sleep. The one participant in the TS group who completed the drop-out form indicated the most challenging aspect of the study was completing the daily questionnaires, however this participant was excluded for inconsistent actigraph compliance (i.e., wore the actigraphy <5 days across both Phase 1 and 2). Interestingly, when asked about what aspects of the study they enjoyed, all participants mentioned either liking the opportunity to get more sleep or enjoying tracking/increased awareness of their sleep. However, all but one teen in the SE group also identified getting more sleep was the most challenging aspect of the study. Consistent with the epidemic of chronic sleep loss among adolescents (NSF, 2006), findings suggest that adolescents struggle with prioritizing sleep despite a desire to obtain more sleep.

Highly relevant to the epidemic of inadequate sleep in teens were the challenges incurred during this study in getting teens to extend their sleep by even a small amount.

Twice as many participants (n=20) were randomized to SE relative to TS (n=10) in order to obtain equivalent group sizes. Although prior research studies have implemented at home SE paradigms with success, most studies have implemented SE in school-aged children (Gruber et al., 2012; Sadeh et al., 2003), for whom parents presumably play a greater role in setting limits around bedtimes and sleep schedules. In a recent study examining the feasibility of at-home sleep extension (i.e., 1.5 hours) among adolescents, an individualized, behaviorally based, in-person problem-solving approach was shown to be effective in extending adolescent sleep (Van Dyk et al., 2017), supporting research suggesting that adolescents benefit from parental involvement around sleep (Short et al., 2011). Further, although there were no group differences on any baseline measures of sleep in the current study, a majority of adolescents endorsed an evening chronotype, consistent with the reliable circadian shift toward an eveningness preference observed during this developmental period (Jenni et al., 2005).

Considering the overall low compliance rate among teens asked to set an earlier bedtime in the current study, public health efforts and policy shifts aimed at delaying school start times in order to increase sleep among adolescents may be more successful. Several school systems in the U.S. have already adopted such changes with evidence of positive outcomes across multiple domains of adolescent functioning (e.g., Boergers, Gable, & Owens, 2014; Wahistrom, 2002). Although a number of schools have seen increased total sleep time and improved academic performance following only small (e.g., approximately 30 minutes) shifts in school start times (Boergers et al., 2014; Wahistrom, 2002), these results have yet to motivate broader, national changes in school start times. Despite the release of a policy statement from the American Academy of Pediatrics in 2014 advocating for later school start times (Owens, Au, Carskadon, Millman, & Wolfson, 2014), evidence from the current study suggests that teens continue to be chronically sleep deprived.

As adolescents in the current study also reported a number of activities (i.e., sports, homework, social activities, etc.) that interfered with their ability to extend their sleep, schools would also benefit from implementing homework reductions, or limits on extracurricular activities (Mousseau et al., 2016). As chronic sleep loss can severely impact the cognitive skills involved in the retention of information (Lebel & Beaulieu, 2011) as well as motor performance and mood (Pilcher & Huffcutt, 1996), further efforts to communicate the importance of sleep among this age group to teachers, school administrators, parents, and other key stakeholders involved in school policy (i.e., facilities management, athletic departments, transportation companies) are essential.

Additionally, as adolescents engage in high levels of technology use and may be more sensitive to blue spectrum light (Hagenauer et al., 2009), these factors likely exacerbate teen sleep loss. Since many teens use multiple forms of technology late into the evening (Calamaro, Mason, & Ratcliffe, 2009), it is possible that sleep hygiene education conducted in schools, combined with parental limit setting, may assist in reducing evening use of technology and potentially lead to increased duration of sleep. However, heightened interests in peer relationships (Brown, 2004; Furman, 2002; O'Brien & Bierman, 1988; Steinberg & Morris, 2001) during this developmental period combined with the fact that technology use can function as a vehicle for peer and social relationships create unique barriers for sleep goals. Thus, future research is needed to both develop and explore the potential effectiveness of policy, public health, and behavioral health interventions to reduce adolescent sleep dept.

Limitations and Future Directions

The current study had several limitations. Firstly, the low compliance rate among the sleep extension group and the subsequently small sample size of participants significantly limited the power of planned analyses in the current study. Further, Type I error has likely been inflated due to the high number of within- and between-group tests completed. Moreover, the current study's use of a 30 minute sleep extension was likely inadequate, as indicated by the lack of a significant change in sleepiness across SE and TS groups. However, the presence of several medium to large effect sizes across the examinations of mood, emotional reactivity, and emotion regulation domains suggest that future research should work to replicate these preliminary findings in a larger sample in which SE can be more reliably manipulated (i.e., in a sleep lab), and provided at larger doses.

When group differences across SE compliant and SE non-compliant (i.e., not included) participants were examined, we found that SE participants who completed the study had significantly higher scores on a broad measure of anxiety and depression (RCADS) than did SE participants who were dropped from the study. This unexpected finding suggests that internalizing symptoms may have impacted compliance with study procedures. As internalizing problems have been associated with greater levels of parental over-involvement in young adults (Schiffrin et al., 2014), differential levels of parental involvement in sleep is also possible. This was not measured in the current study but represents an important question for future investigations. Most importantly, a difference in internalizing symptoms suggests that the SE group included in this study may be more representative of adolescents with some internalizing problems, rather than a psychologically healthy community sample.

It is important therefore that future studies examine the feasibility of at-home sleep extension in larger samples of adolescence with variable levels of psychological problems.

Although there were no differences in age or pubertal status between SE and TS groups in the current study, these factors are strongly associated with overall sleep need, sleep timing, and emotion regulation skill. Specifically, with age, total sleep time decreases (Crabtree & Williams, 2009), circadian timing becomes more skewed toward an evening chronotype (Jenni et al., 2005), and emotion regulation skill (i.e., cognitive reappraisal) improves (McRae et al., 2012; Silvers et al., 2012). The present study did not consider the effect of these developmental variables despite their importance. Thus, findings of the current study should be confirmed in future research utilizing larger samples, and should include a careful examination of the interplay between age, puberty, sleep, and emotion regulation. Additionally, the current study was not able to rule out the presence of any sleep disorders undetected by the clinical sleep interview. Thus, future work should include a more comprehensive assessment of potential sleep disorders using the gold standard of polysomnography.

Finally, caffeine use was not assessed on the day of the in-lab experimental tasks and it is possible that some participants' emotional reactivity and emotion regulation skills were impacted by caffeine use. As many adolescents use caffeine relatively regularly to combat the effects of chronic sleep deprivation (Ludden & Wolfson, 2010), future work should examine both the impact of sleep, in addition to caffeine use, on the various aspects of emotional functioning. Although participants were randomized to TS and SE groups, participants who did not complete the SE condition (i.e., due to non-compliance) had significantly lower scores of overall anxiety/depression than did SE participants who completed the study. This difference across SE completers and non-completers suggests that SE participants in the current study may not be a representative sample of healthy teens; instead, SE participants may be more representative of adolescents with subclinical internalizing symptoms. Thus, results of the current study must be replicated in a representative sample of healthy teens.

Further, results may not be generalizable to younger populations, or to adolescents with preexisting clinically diagnosed psychological or sleep-related disorders. Just as changes in age, underlying psychopathology, and the presence of a sleep disorder may alter the associations between sleep and emotional constructs assessed in the current study, future work should explore the association between increasing sleep time and subsequent changes in emotion regulation skill among clinical populations. This future direction is particularly important, as sleep may offer a strategic point of intervention for improving emotional processes underlying psychopathology in adolescents.

Due to our low rates of compliance, and thus small sample size, the current study was unable to examine daily changes in positive and negative mood. Although there were no visible trends in daily mood data across groups, future studies should examine daily changes in positive and negative mood within larger samples, utilizing more complex within-subject time series analyses. Such analyses will facilitate the exploration of the association between sleep on specific nights of the week and mood the following day(s).

Lastly, although the current study utilized a comprehensive battery of psychosocial measures at baseline, the impact of ongoing stressors on participant's sleep and emotional functioning was not assessed in the current study. As both sleep and affect are highly impacted by environmental factors (Martin et al., 2017; Mousseau et al., 2016), future research should work to incorporate ongoing stressors into examinations of sleep, emotion, and emotion regulation.

Conclusions and Implications

Despite these limitations, the current study makes several meaningful contributions to the current literature. Although SE was difficult to accomplish in the home environment for this sample of healthy teens, preliminary data from this study suggest that extending sleep for an average of 30 minutes for 5 nights improved adolescents' emotion regulation skills. Specifically, healthy adolescents who extended their sleep showed more (appropriate) emotional reactivity in facial expressions in the context of a frustrating experience. Further, adolescents who extended their sleep were able to both up-regulate their own emotions (i.e., subjectively reported arousal and valence) and put forth greater effort (i.e., increase total word count) in the context of an explicit social emotional goal. Collectively, findings from the present study suggest that even a small amount of additional sleep may reduce "blunting" of emotional reactivity and enhance emotion regulation skills, which could facilitate social competence and better promote positive peer relationships among adolescents. The extent to which such changes in emotional functioning could be protective against affective risk during this developmental period remains to be investigated.

As differences in subjective sleepiness, daily mood, and emotional reactivity were expected but not observed, the relative chronic levels of sleep deprivation in this sample was likely not adequately alleviated by 5 nights of 30 additional minutes of sleep. Thus, results may imply that while aspects of emotional reactivity and emotion regulation skills were improved by additional sleep, further emotional changes may only occur if teens are able to achieve total sleep times closer to the recommended 9-10 hours.

Future research should work to further understand the dose response effect of SE across the domains of mood, emotional reactivity, and emotion regulation skill among both healthy and psychologically complicated adolescents. As additional sleep is linked with improved emotional functioning, and potentially with improved social and psychological functioning, future research should work to explore the barriers that interfere with SE among adolescents.

As one of the few studies to utilize both subjective and objective measurements of emotion simultaneously, the current study expands upon prior work through multimodal assessment of emotion, as well as through the use of an active and engaging series of socially-relevant tasks. The tasks used in the current study created an environment in which emotional goals were manipulated, and thus the process of emotion regulation was able to be assessed (Mauss & Tamir, 2013). This approach greatly expands upon the use of passive reactivity tasks utilized in prior research, in which participants have been asked to react to images (Berger et al., 2012; Franzen et al., 2009; Gujar et al., 2010; Leotta et al., 1997; Wagner et al., 2002), sounds (McMakin et al., 2016), movie clips (Minkel et al., 2011), or discuss past conflicts (McMakin et al., 2016). Although the emotion regulation task used in the current study requires additional research, it may present a more naturalistic yet controlled method of examining emotional reactivity and emotion regulation among adolescents. Such methodological developments in the measurement of emotion are highly relevant to the future of emotional research in childhood and adolescence.

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Table 1.

Sample Demographics

	TS		SE		Group Differences	
	n = 10		*n = 10*			
	n	***%***	***n***	***%***	χ^2	***p***
Female	6	60%	6	60%	0	1
Marital status					3.33	0.50
Married	7	70%	8	80%		
Single	1	10%	-	-		
Divorced	1	10%	2	20%		
Separated	1	10%	-	-		
Ethnicity/Race					4.17	0.22
Caucasican	5	50%	3	30%		
AfricanAmerican	1	10%	3	30%		
Asian	2	20%	-	-		
Latino/a	2	20%	4	40%		
Mother's highest Educ					2.14	0.71
Some grade school	1	10%	-	-		
High school degress	1	10%	3	30%		
Some college	2	20%	2	20%		
College degree	2	20%	2	20%		
Advanced degree	4	40%	3	30%		
Father's highest Educ					6.44	0.17
Some grade school	1	10%	2	20%		
High school degress	1	10%	1	10%		
Some college	1	10%	2	20%		
College degree	7	70%	2	20%		
Advanced degree	-	-	3	30%		
	M	***SD***	***M***	***SD***	***t*-test**	***p***
Age	15.8	1.22	15.7	0.674	-0.23	0.82
Average # people in household	4.2	1.03	5	1.76	1.22	0.23
Pubertal Development Scale	3.59	0.53	3.54	0.65	-0.2	0.84
CMEP Score	31.88	5.1	35	4.21	1.63	0.12
Tech Frequency	17.6	2.98	16.66	1.56	-0.94	0.36
Bedtime Technology	14.4	2.75	12.9	3.07	-1.15	0.27
Total Technology Use	32	5.39	29.5	3.7	-1.21	0.24

Note. ** $p < 0.01$; * $p < 0.05$; TS = Typical Sleep; SE = Sleep Extension; Ns = non-significant; CMEP = Children's Morning Eveningness Preference; Age in the TS group ranged from 14-17 years; Age in the SE group ranged from 15-17 years

Table 2.

Psychological Variables across SE Compliant and SE Non-Compliant Participant Groups

	SE Compliant		**SE Non-Compliant**		**Group Differences**		**95% Confidence Interval of the Difference**	
	M	***SD***	***M***	***SD***	***t***	***p***	**Lower**	**Upper**
Age	15.70	0.67	15.10	0.74	-1.90	0.07	-1.26	0.06
Pubertal Status	3.54	0.65	3.32	0.74	-0.71	0.49	-0.87	0.43
CMEP Score	35.00	4.22	33.60	4.58	-0.71	0.49	-5.53	2.73
Tech Frequency	16.60	1.58	17.60	4.03	0.73	0.48	-1.88	3.88
Bedtime Technology	12.90	3.07	14.50	3.47	1.09	0.29	-1.48	4.68
Total Technology Use	29.50	3.72	32.10	7.00	1.04	0.31	-2.67	7.87
CBCL Internalizing Pbms.	39.70	14.10	50.00	9.81	1.83	0.09	-1.60	22.20
CBCL Externalizing Pbms.	42.60	7.01	48.44	5.00	2.07	0.05	-0.12	11.80
CBCL Total Problems	41.20	11.74	47.33	8.72	1.28	0.22	-3.97	16.24
RCADS Total Score	44.35	6.51	36.90	6.26	-2.61	0.02*	-13.44	-1.44
DTS Total	2.28	0.42	1.88	0.47	-2.00	0.06	-0.82	0.02

Note. ** $p < 0.01$; * $p < 0.05$; SE = Sleep Extension; CMEP = Children's Morning Eveningness Preference; CBCL = Child Behavior Checklist; Pbms.= Problems; RCADS = Revised Child Anxiety and Depression Scale; DTS = Distress Tolerance Scale;

Table 3.

Demographic Variables across SE Compliant and SE Non-Compliant Participant Groups

	SE Compliant		**SE Non-Compliant**		**Group Differences**	
	n	**%**	***n***	**%**	χ^2	***p***
Female	6	60%	6	60%	*0*	1
Marital status					2.4	0.49
Married	8	80%	8	80%		
Single	-	-	1	10%		
Divorced	2	20%	1	10%		
Separated	-	-	-	-		
Ethnicity/Race					6.67	0.16
Caucasian	3	30%	6	60%		
African American	3	30%	-	-		
Asian	-	-	1	10%		
Latino/a	4	40%	2	20%		
More than 2 races	-	-	1	10%		
Mother's highest Educ					1.73	0.79
Some grade school	-	-	1	10%		
High school degrees	3	30%	2	20%		
Some college	2	20%	1	10%		
College degree	2	20%	3	30%		
Advanced Degree	3	30%	3	30%		
Father's highest Educ					0.69	0.95
Some grade school	2	20%	1	10%		
High school degrees	1	10%	1	10%		
Some college	2	20%	2	20%		
College degree	2	20%	3	30%		
Advanced Degree	3	30%	2	20%		

Notes. ** $p < 0.01$; * $p < 0.05$; SE = Sleep Extension; Educ = education

Table 4.

Sleep Parameters by Group

	TS		SE		Group Differences [S]		
	M	***SD***	***M***	***SE***	***F***	***p***	$_{partial}\eta^2$
Actigraphy Measures							
Phase 1 TST	453.97	63.86	390.99	33.03	1.77	0.20	0.090
Phase 1 SOL	12.10	12.18	6.69	4.47	0.86	0.37	0.048
Phase 1 WASO	15.92	8.92	18.2	7.44	0.007	0.94	0.000
Phase 1 SlpEff	96.61	2.21	94.58	4.13	0.60	0.45	0.034
Phase 2 TST	415.17	41.35	449.42	47.23	9.64	0.01**	0.380
Phase 2 SOL	8.16	6.37	11.30	9.08	3.92	0.07	0.197
Phase 2 WASO	11.74	11.94	26.55	19.36	3.34	0.09	0.173
Phase 2 SlpEff	97.26	2.82	94.61	3.83	2.36	0.14	0.129
ESS							
At Baseline	9.00	5.10	6.10	2.42	1.15	0.30	0.06
Following Phase 2	11.30	4.95	7.40	3.81	0.22	0.64	0.01

Note. ** $p < 0.01$; * $p < 0.05$; ANOVAs were used to compare baseline week sleep parameters; ANCOVAs controlling for each baseline parameter were used to compare experimental week sleep parameters; TS = Typical Sleep; SE = Sleep Extension; [S] summer participation was entered as a covariate for all group comparisons; Phase 1 = first 7 nights of at-home sleep monitoring; Phase 2 = final 5 nights of sleep manipulation after randomization to SE or TS group; TST = total sleep time; SOL = sleep onset latency; WASO = wake after sleep onset; SlpEff = sleep efficiency; ESS = Epworth Sleepiness Scale;

Table 5.

Bivariate Correlations: Correlations for POMS Subscales and Weekly Mood Measures

		1	2	3	4	5	6	7	8
1	Baseline POMS Vigor	1							
2	Baseline POMS Total Mood Disturbance	-.646**	1						
3	In-Lab POMS Vigor	.527*	-0.137	1					
4	In-Lab POMS Total Mood Disturbance	-0.203	0.333	-.545*	1				
5	Phase 1– Avg Neg Mood	-0.225	.690**	0	0.382	1			
6	Phase 1– Avg Pos Mood	.564**	-0.179	0.296	0	0.01	1		
7	Phase 2– Avg Neg Mood	0.004	0.27	-0.075	0.197	.742**	0.095	1	
8	Phase 2– Avg Pos Mood	.626**	-0.32	0.211	0.034	-0.161	.951**	-0.046	1

Note. ** $p < 0.01$; * $p < 0.05$; POMS = Profile of Mood States; Phase 1 = first 7 nights of at-home sleep monitoring; Phase 2 = final 5 nights of sleep manipulation after randomization to SE or TS group; Avg Neg Mood = Average negative mood rating; Avg Pos Mood = Average positive mood rating; Baseline measures were completed at the first appointment; In-Lab measures were completed following Phase 1 and Phase 2 of the at-home monitoring period, immediately prior to the computerized interaction and game tasks;

Table 6.

Bivariate Correlations: Correlations for Emotional Reactivity Measures

		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
1	SAM Arousal – Computer Game	1							
2	SAM Valence – Computer Game	0.242	1						
3	Computer Game Frustration Rating	-0.065	-0.645**	1					
4	LIWC TWC - Int 1	0.167	0.169	-0.214	1				
5	LIWC Pos. Emotion - Int 1	0.071	-0.309	0.229	.462*	1			
6	LIWC Neg. Emotion - Int 1	-0.128	-0.215	0.317	-0.057	0.093	1		
7	Facial Expression Valence- Computer Game	0	0.1	-0.211	-0.199	-0.439	-0.175	1	
8	Facial Expression Valence Variance - Computer Game	0.294	0.031	-0.131	0.222	0.443	-.628**	-0.198	1

Note. ** $p < 0.01$; * $p < 0.05$; SAM = Self-Assessment Manikin; LIWC = Linguistic Inquiry and Word Count; Int 1 =non-manipulated social interaction; TWC = Total word count; Pos. Emotion= positive emotional language; Neg. Emotion = negative emotional language

Table 7.

Bivariate Correlations: Emotion Regulation Variables

		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
1	SAM Arousal - Int 1	1										
2	SAM Valence - Int 1	0.43	1									
3	SAM Arousal - Int 2	.703**	0.192	1								
4	SAM Valence - Int 2	0.107	0.149	0.35	1							
5	LIWC TWC - Int 1	-0.119	0.154	-0.167	-0.115	1						
6	LIWC Pos. Emotion - Int 1	0.112	-0.092	0.086	0.174	.462*	1					
7	LIWC Neg. Emotion - Int 1	0.035	-0.075	-0.046	-0.292	-0.057	0.093	1				
8	LIWC Total Word Count - Int 2	-0.091	-0.017	-0.126	0.019	.656**	0.347	0.078	1			
9	LIWC Pos. Emotion - Int 2	-0.063	0.092	0.29	0.415	0.215	.454*	0	0.282	1		
10	LIWC Neg. Emotion - Int 2	0.031	0.188	-0.061	-0.28	0.335	0.113	-0.162	0.057	-0.058	1	
11	PASAT Quit time	0.033	0.251	0.271	0.026	-0.181	-0.169	0.085	-0.183	0.218	0.339	1

Note. ** $p < 0.01$; * $p < 0.05$; SAM = Self-Assessment Manikin; LIWC = Linguistic Inquiry and Word Count; Int 1 =non-manipulated social interaction; Int 2 = manipulated social interaction; TWC = Total word count; Pos. Emotion = positive emotional language; Neg. Emotion= Negative emotional language; PASAT = Paced Auditory Serial Addition Task;

Table 8.

POMS and Weekly Mood Ratings Repeated Measures Results

	SE		TS		Group*Time			90% CI		Main effect of Time			90% CI		Main effect of Group			90% CI	
	M	*SD*	*M*	*SD*	*F*	*p*	$_{partial}\eta^2$	LCI	UCI	*F*	*p*	$_{partial}\eta^2$	LCI	UCI	*F*	*p*	$_{partial}\eta^2$	LCI	UCI
POMS Vigor					0.01	0.91	0.00	0.00	0.02	0.34	0.57	0.02	0.00	0.19	0.51	0.49	0.03	0.00	0.21
Pre	5.60	3.86	5.35	3.02															
Post	6.20	2.86	5.00	2.79															
POMS Mood Disturbance					0.22	0.65	0.01	0.00	0.18	0.02	0.90	0.00	0.00	0.04	0.27	0.61	0.02	0	0.19
Pre	1.40	8.21	-0.12	6.74															
Post	1.10	6.19	1.50	9.07															
Positive Mood					0.85	0.37	0.05	0.00	0.25	2.58	0.13	0.13	0.00	0.36	2.20	0.16	0.12	0.00	0.34
Phase 1 Avg	21.97	6.56	17.36	7.63															
Phase 2 Avg	20.33	7.42	16.67	7.27															
Negative Mood					0.03	0.87	0.00	0.00	0.06	1.46	0.24	0.08	0.00	0.30	0.10	0.76	0.01	0.00	0.14
Phase 1 Avg	7.29	2.76	5.62	3.00															
Phase 2 Avg	8.19	3.37	6.43	3.17															

Note. ** $p < 0.01$; * $p < 0.05$; Summer participation was included as a covariate in all models; CI = 90% Confidence Interval; LCI = Lower Confidence Interval, UCI = Upper Confidence Interval; POMS = Profile of Mood States; Phase 1 = first 7 nights of at-home sleep monitoring; Phase 2 = final 5 nights of sleep manipulation after randomization to SE or TS group

Table 9.

Emotional Reactivity ANCOVA Models

ANCOVA Outcome Variable	SE		TS		Group Differences		Effect Sizes				
	M	SD	M	SD	F	p	$_{partial}\eta^2$	$_{Adj}R^2$	d	CI Lower	CI Upper
Computer Game - SAM Arousal	5.60	2.27	4.90	1.66	0.51	0.49	0.03	-0.08	0.32	-0.56	1.20
Computer Game - SAM Valence	4.40	2.72	4.50	0.85	0.00	1.00	0.00	-0.12	0.00	-0.88	0.88
Computer Game Frustration Ratings	7.00	2.83	5.50	2.12	0.99	0.33	0.06	-0.02	0.44	-0.44	1.33
Facial Expression Valence	-0.35	0.31	-0.12	0.05	3.80	0.07	0.19	0.15	0.87	-0.05	1.79
Facial Expression Valence Variability	0.09	0.04	0.08	0.06	1.44	0.25	0.08	0.02	0.54	-0.36	1.43
LIWC TWC - Int 1	480.60	177.53	482.90	165.59	0.71	0.41	0.04	0.00	0.38	-0.51	1.26
LIWC Pos. Emotion - Int 1	4.56	1.71	3.96	1.02	0.65	0.43	0.04	-0.06	0.36	-0.52	1.24
LIWC Neg. Emotion - Int 1	0.64	0.34	0.73	0.50	0.17	0.68	0.01	-0.11	0.18	-0.69	1.06

Note. ** $p < 0.01$; * $p < 0.05$Summer participation was included as a covariate in all models; SAM = Self-Assessment Manikin; LIWC = Linguistic Inquiry and Word Count; TWC = Total word count; Pos. Emotion = positive emotional language; Neg. Emotion= Negative emotional language; Int=social interaction; CI = 95% Confidence Interval

Table 10.

Emotion Regulation Models

	SE		TS		Group*Time			90% CI		Main effect of time			90% CI		Main effect of Group			90% CI	
	M	*SD*	*M*	*SD*	*F*	*p*	$_{partial}\eta^2$	LCI	UCI	*F*	*p*	$_{partial}\eta^2$	LCI	UCI	F	p	$_{partial}\eta^2$	LCI	UCI
SAM Arousal					0.51	0.49	0.03	0.00	0.21	2.75	0.12	0.14	0.00	0.37	0.89	0.36	0.05	0.00	0.27
Int 1	3.90	2.13	3.80	1.87															
Int 2	4.90	2.23	3.80	1.93															
SAM Valence					1.15	0.30	0.06	0.00	0.28	0.42	0.53	0.02	0.00	0.20	0.56	0.47	0.03	0.00	0.22
Int 1	5.90	2.18	6.80	0.63															
Int 2	6.70	0.95	6.60	0.52															
LIWC TWC					1.89	0.19	0.10	0.00	0.33	0.17	0.69	0.01	0.00	0.17	0.09	0.77	0.01	0.00	0.14
Int 1	480.60	177.53	482.90	165.59															
Int 2	547.70	184.81	491.70	144.14															
LIWC Pos. Emotion					0.67	0.42	0.04	0.00	0.13	0.18	0.67	0.01	0.00	0.17	0.17	0.69	0.01	0.00	0.17
Int 1	4.56	1.71	3.96	1.02															
Int 2	4.39	1.80	4.54	1.18															
LIWC Neg. Emotion					0.06	0.81	0.00	0.00	0.12	0.94	0.35	0.05	0.00	0.27	0.03	0.87	0.00	0.00	0.06
Int 1	0.64	0.34	0.73	0.50														95%	95%
Int 2	0.95	0.52	1.01	0.90														LCI	UCI
PASAT Quittime	357.80	115.42	369.60	99.28											0.06	0.81	*d* = .11	-0.77	0.99

Note. Summer participation was included as a covariate in all models; SAM = Self-Assessment Manikin; TWC = Total word count; Pos. Emotion = positive emotional language; Neg. Emotion= Negative emotional language; Int=social interaction; CI = 90% Confidence Interval; LCI = Lower CI; UCI = Upper CI

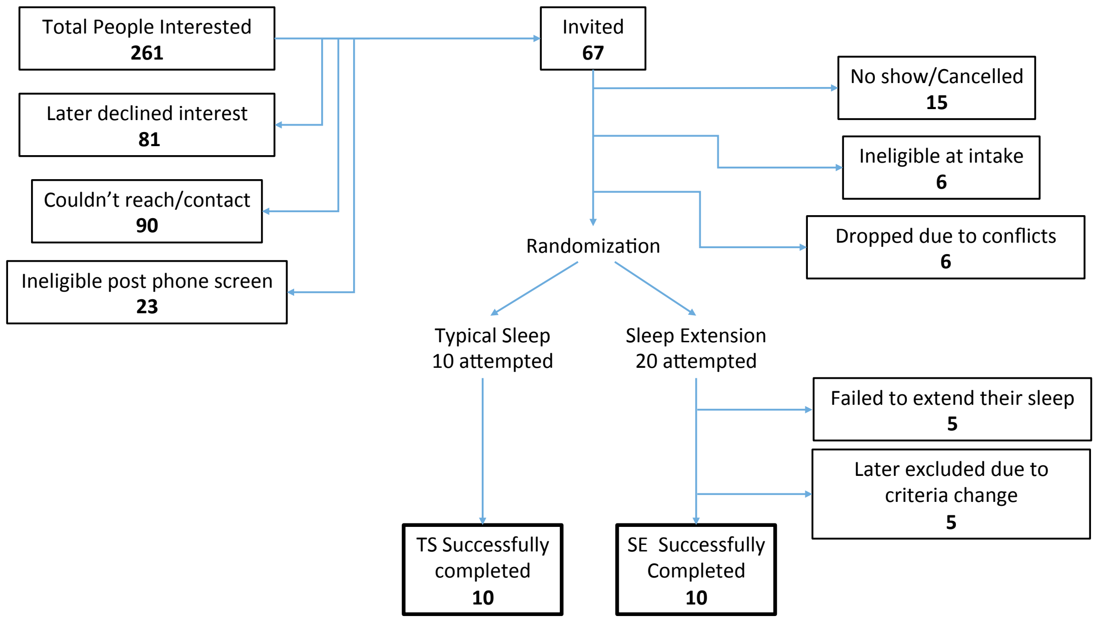
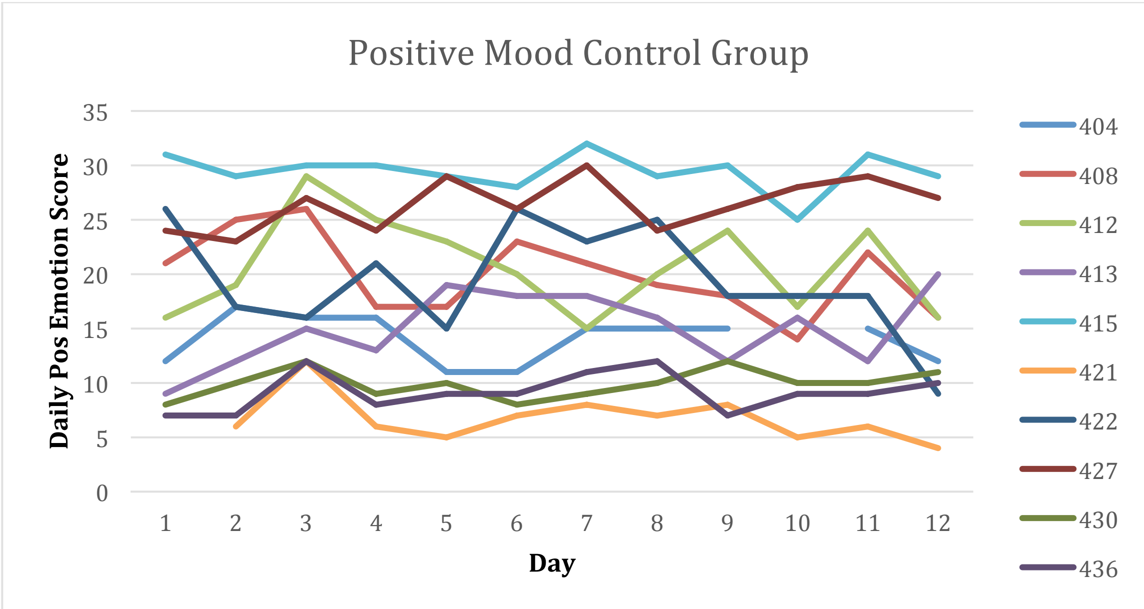


Figure 1. Participant Flow Chart of Recruitment and Drop Out Rates



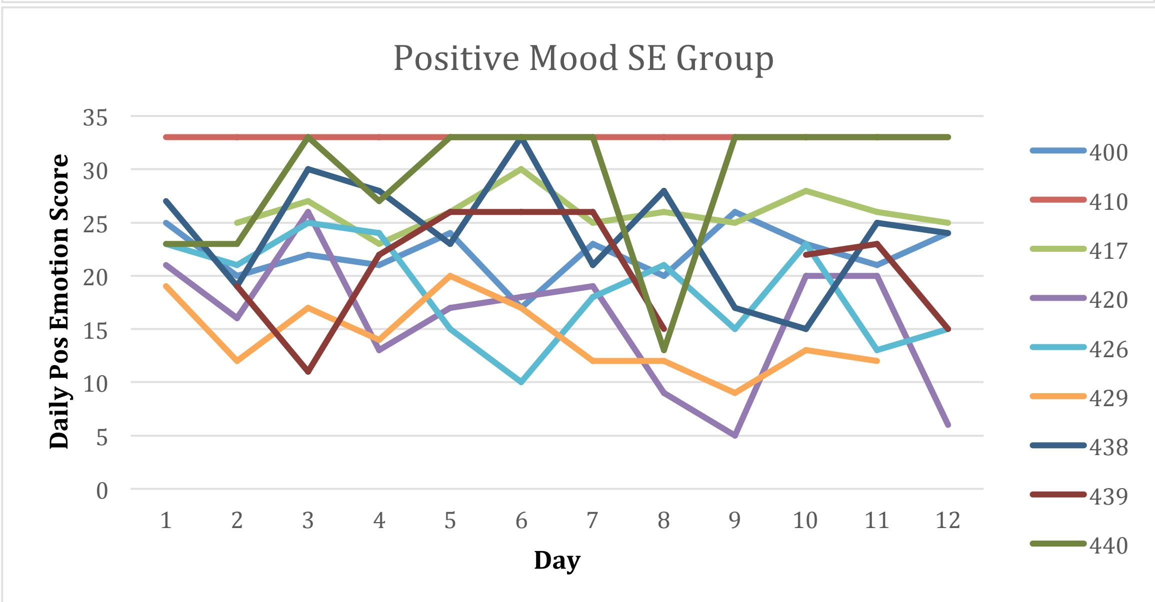


Figure 2. Positive Mood trends by Group over 12 days of At Home Participation

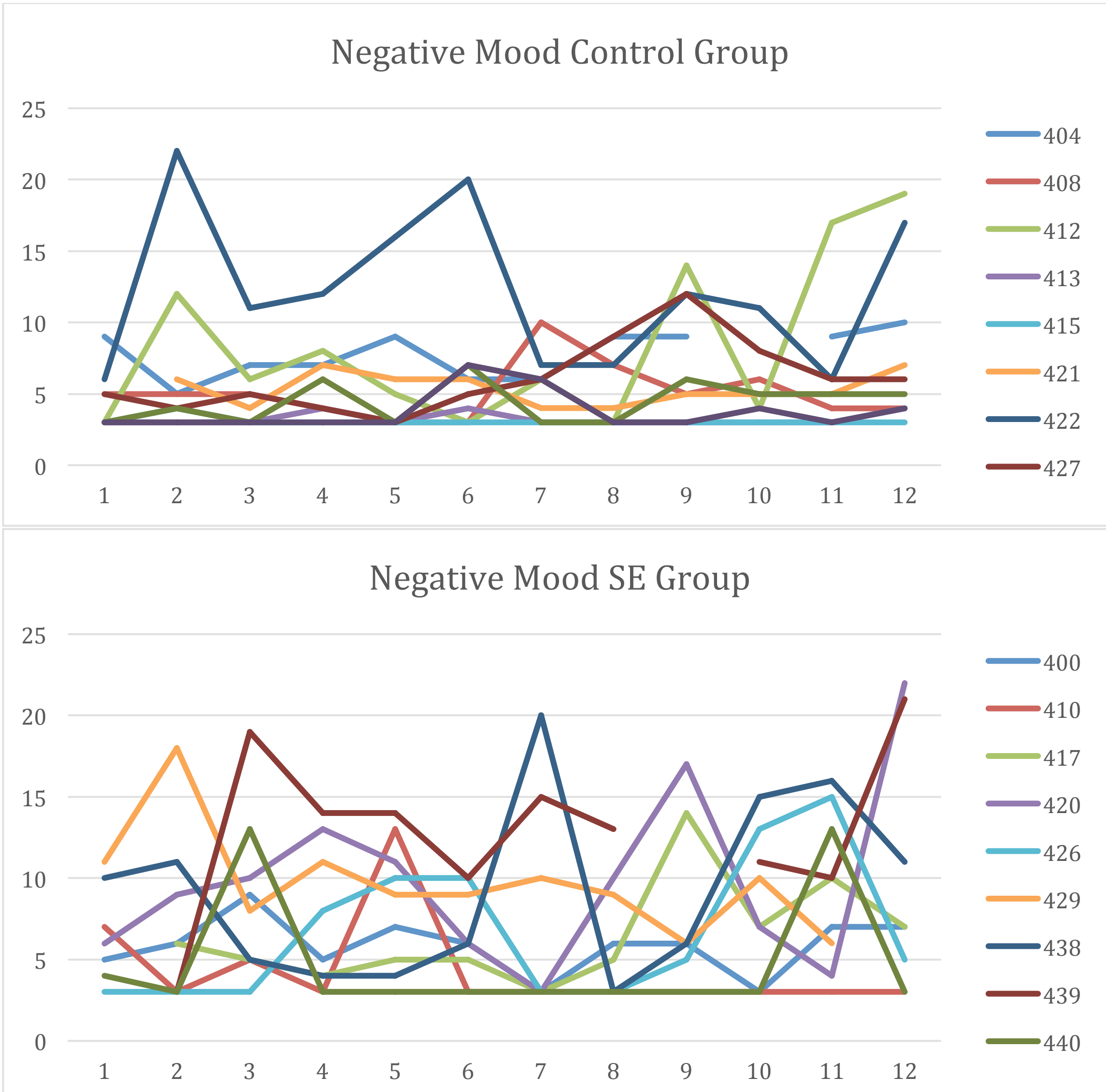


Figure 3. Negative Mood trends by Group over 12 days of At Home Participation

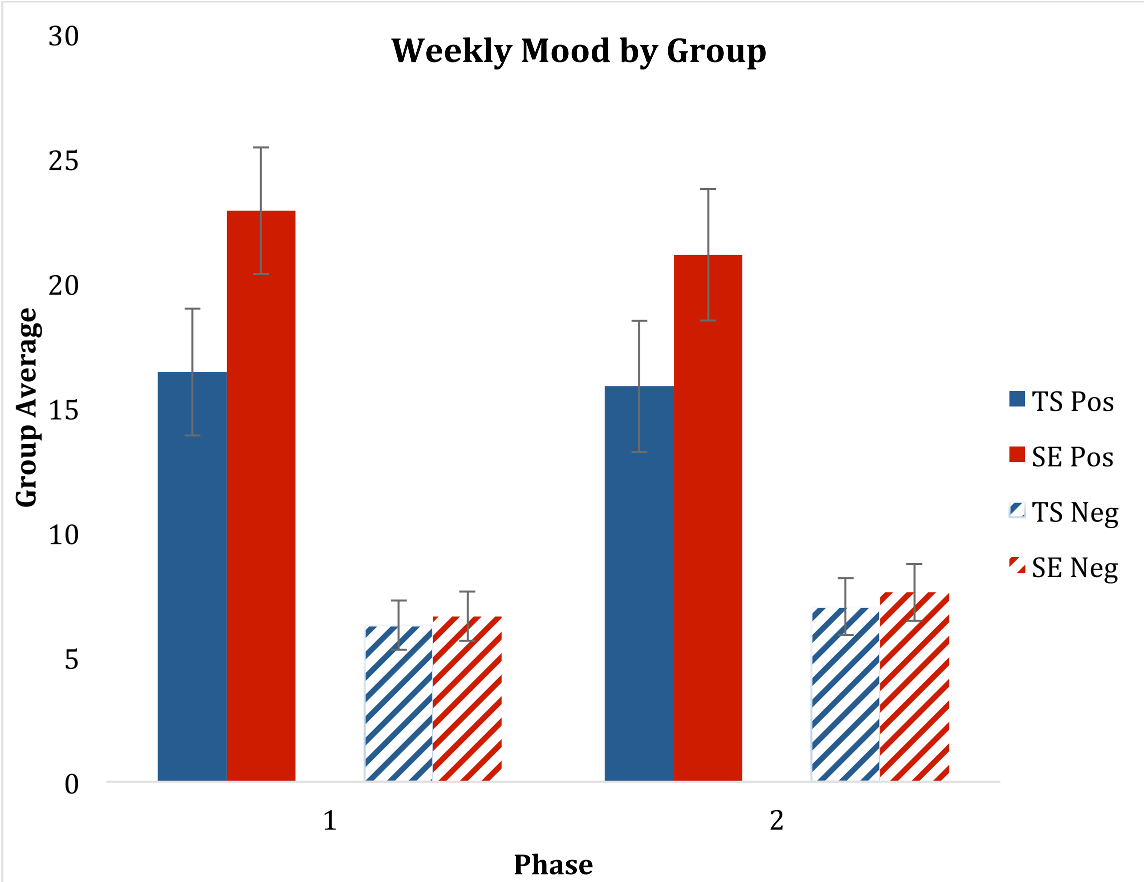


Figure 4. Averages of self reported positive and negative emotion by group across Phases 1 and 2 of the at-home sleep monitoring period; TS = Typical Sleep; SE = Sleep Extension

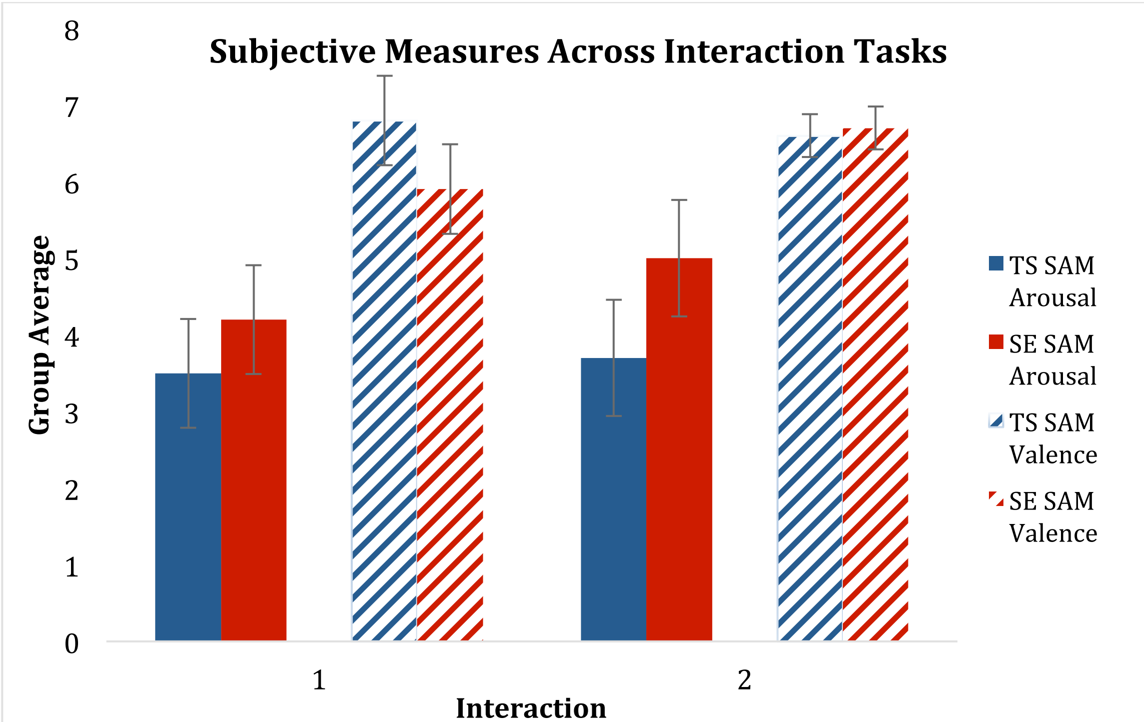


Figure 5. SAM Arousal (0 = low arousal, 8 = high arousal) and Valence (0 = negative mood, 8 = positive mood) score changes by group across the non-manipulated and the manipulated social interaction tasks for Typical Sleep (TS) and Sleep Extension (SE) groups.

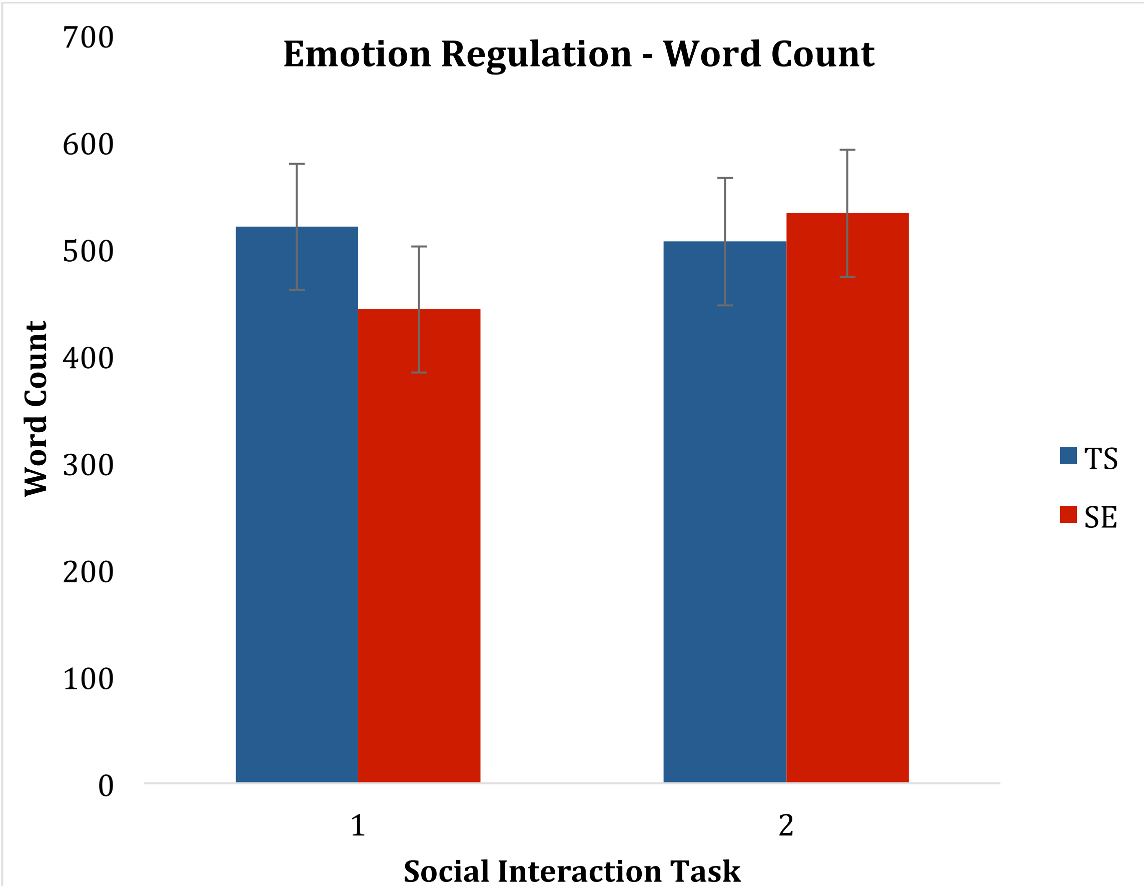


Figure 6. Changes in LIWC (Linguistic Inquiry and Word Count) scored total word count by group across the non-manipulated and the manipulated social interaction tasks for Typical Sleep (TS) and Sleep Extension (SE) groups.

Appendix A

Technology Use Questionnaire

DIRECTIONS: Please answer the following questions about technology use based on the following scale:

(1) Never
(2) one to three times a month
(3) about once a week
(4) several times a week
(5) every day

	Never	**2-3 Times per Month**	**Once per Week**	**Several Times Per Week**	**Every Day**
How often do you send/receive text messages?	1	2	3	4	5
How often are you woken up at night by incoming text messages on your mobile phone?	1	2	3	4	5
How often do you watch TV?	1	2	3	4	5
How often do you watch TV in the evening?	1	2	3	4	5
How often do you watch TV when falling asleep?	1	2	3	4	5
How often do you video chat?	1	2	3	4	5
How often do you video chat before bed?	1	2	3	4	5
How often do you play computer games?	1	2	3	4	5
How often do you play computer games in the evening before bed?	1	2	3	4	5
How often do you use social media?	1	2	3	4	5
How often do you use social media in the evening before bed?	1	2	3	4	5

Appendix B

Daily Mood Questionnaire

Today, how much did you feel.....

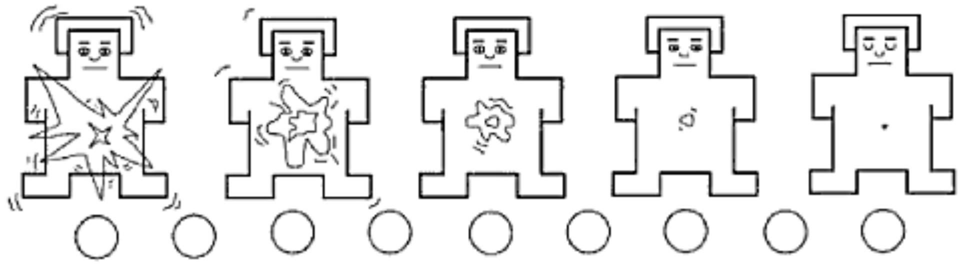
	Not at all										A lot
Nervous/Worried	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Sad	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Angry	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Tired	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Amused/Silly	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Loving/Warm	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Happy	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**

Appendix C

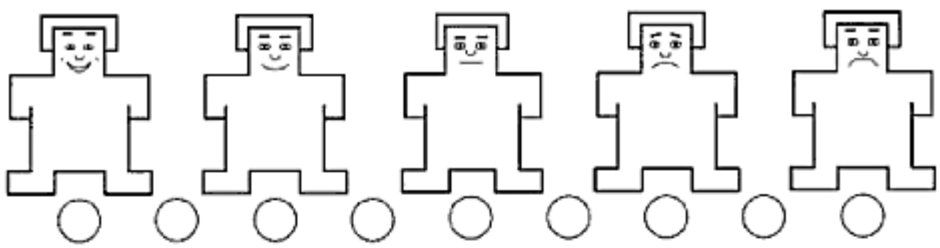
Participant ID:______ Date:_________

Interaction Task Response Form

How excited/jittery or calm/bored did you feel did you feel <u>during the interaction</u>?



How happy or bad did you feel during the interaction?



Ho much effort did you put into this interaction?

0	1	2	3	4	5	6	7	8	9	10

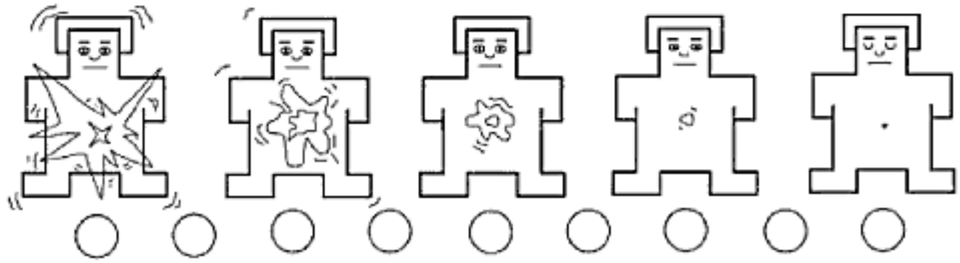
No effort at all
Extreme effort

Appendix D

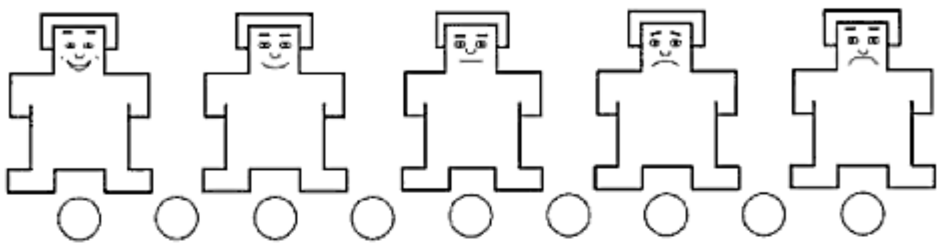
Participant ID:_______ Date:__________

Computer Game Response Form

How excited/jittery or calm/bored did you feel did you feel <u>during the game</u>?



How happy or bad did you feel during the game?



How frustrating was this game?

	0	1	2	3	4	5	6	7	8	9	10
Not at all Frustrating										Extremely	

Appendix E

University of Houston Post-Research Study Survey

Thank you for participating in our research project! We have one last set of question to ask you to so that we can improve the way we do research here at UH.

1. How much did you enjoy the current study?

Not at all										**A lot**
0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**

2. What did you enjoy the most about the current study?

____
____
____

3. What did you enjoy the least about the current study?

____
____
____

4. What was the purpose of the current study?

____
____
____

5. What do you think the researchers are interested in finding?

____
____
____

6. Did you interact with other participants in the current study?

   _____Yes _____No

   a. If yes, did you enjoy the interaction?

      _____Yes _____No

   b. Who were the people you interacted with?

      ____

   c. Would you want to talk with these people again if given the opportunity?

      _____Yes _____No

   d. Why or Why not?

      ____
      ____

7. Do you think the researchers were honest?

   _____Yes _____No

   a. Why or Why not?

Appendix F

Adolescent Sleep Extension Study (ASES) Telephone Screener			
Person Completing Screen			
Today's Date			
Demographic Information		**Exclusion Criteria**	**Inclusion Criteria**
Referral Source			
Child's Name			
Parents Name			
Sex			
DOB			
Age			
Ethnicity/Race			
Does child live with you full time?			
Address			
Phone Numbers (indicate preferred number)			
Home			
Work			
Cell			
Email Address			
Languages Spoken in the home (and what is primary)		Not English [ ]	English Primary [ ]
School			
Grade			
Enrolled in Regular Education Classes?		SPED/Home Schooled [ ]	Regular Ed [ ]
Medical History		**Exclusion Criteria**	**Inclusion Criteria**
Does your child have a medical condition or diagnosis that requires routine medical care?			
Recurrent ear infections and/or strep throat?			
if yes, how often?			

Has any health professional ever expressed concern about your child's weight? (if yes, what is the specific concern?)			
Current Medications			
reasons			
Previous medications			
reasons		Medical routine or medications that interfere with sleep [ ]	No Concerns [ ]
Sleep Questions		**Exclusion Criteria**	**Inclusion Criteria**
Snoring/Gasping while your child is asleep?			
(If yes) From one room away?			
(If yes) history or current bedwetting?			
(If yes) tonsils / adenoids removed?			
(If yes) recurrent ear infections/strep?			
Excessive daytime sleepiness?			
Mouth breathing while asleep			
Excessive Movement during sleep/Restless movement?			
Use of medication/sleep aids to get to sleep?		Evidence of Sleep Disorders [ ]	No Sleep Disorders [ ]
CIRCADIAN SLEEP DISORDERS		**Exclusion Criteria**	**Inclusion Criteria**

What does your child's typical sleep schedule looks like? (ask for weekdays and weekends and determine if there is a discrepancy)			
does your child have trouble getting to sleep? Getting up for school?		Evidence of Sleep Disorders [ ]	No Evidence of Sleep Disorders [ ]
PSYCHIATRIC HISTORY		**Exclusion Criteria**	**Inclusion Criteria**
Current Psychiatric Treatments/Diagnoses		Yes[ ]	No [ ]
If no or unsure, current significant emotional or behavioral problems that you are currently **interested in getting treatment for**?		Yes[ ]	No [ ]
Previous Psychiatric Treatments/Diagnoses			
does your child show any <u>current</u> thoughts, behaviors, or gestures of hurting self? (If yes, ask them to go to the nearest emergency room)		Yes[ ]	No [ ]
Family Psychiatric History			
Other Comments			
		Exclude?	**Include?**
Yes/No		Y/N	Y/N

To be completed by the Screener	
If eligible w/o Concerns	SCHEDULE:
If eligible <u>with</u> concerns	Availability for baseline & follow up appointment
Baseline (X hrs)	
1 week f/u apt (x hrs)	
Best time to be reached	
If ineligible, why?	

Appendix G

Confederate Instructions

Interaction 1

Directions to Both: Try to get to know the other person. You will be given 5 minutes to talk.

The participant has been instructed to get to know you. Please engage with them as you would with a potential classmate or someone else you are trying to get to know for the first time. However, please refrain from trying to accommodate the participant—you are equal partners in this exercise, both trying to get to know the other.

After any 3 second pause, you may ask about or comment one of the following topics:

- Weather
- neighborhood
- school
- recent movies
- sports
- clubs
- plans for the weekend
- family/siblings

Interaction 2

Directions to **Both**: Try to get to know the other person. You will be given 5 minutes to talk.

Additional Directions to Participant: "The next person you're going to interact with is ready now and we need to get started since we're behind schedule. Again, try to get to know her as if she was a new roommate or neighbor. One thing though: she is pretty upset about losing her phone. We really appreciate her participating in this study also, so would you please try your best to cheer her up when you talk with her? (Ask for affirmative response from participant)"

Additional Directions to the Confederate: Open the interaction with the statement below. Your facial expressions should communicate anxiety or worry, your vocal cadence should be slightly faster than your normal speech, and it should be louder and higher pitch in any sentence followed by an explanation mark. Act as if this had indeed happened to you for the remainder of the interaction, but maintain awareness of the interaction—in other words, do not purposefully brood about losing the phone. After opening with this information, if there is a 3 second pause you may ask about or comment on any topic from the list above.

SAY: "I'm sorry I'm late. I lost my phone. I'm freaking out because my parents just bought it for me. Anyway, my name is______."