AMBIENT LIGHT AND SLEEP IN COMMUNITY DWELLING OLDER ADULTS

By

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A THESIS PRESENTED TO THE GRADUATE SCHOOL
OF THE UNIVERSITY OF FLORIDA IN PARTIAL FULFILLMENT
OF THE REQUIREMENTS FOR THE DEGREE OF
MASTER OF SCIENCE

UNIVERSITY OF FLORIDA

2008

To all who light up life

ACKNOWLEDGMENTS

I would like to thank my chair Dr. Christina McCrae for her intellectual guidance and constant mentoring; my supervisory committee members for their time and recommendations; the Sleep Research Lab for their support, Amanda Ross, Natalie Dautovich, Joseph MacNamara, and Joseph Dzierzewski; my parents, Richard and Rozann Stripling for their unconditional love and unvarying support through my entire educational process; and Rome Cagnina for editing countless copies of this work.

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May 2008

Chair: Christina McCrae
Major: Psychology

Research has shown overall ambient light relates to various aspects of objective nighttime sleep. However, less research has been conducted examining the relationship between daytime ambient light exposure and subjective sleep. The present study will look more closely at ambient light (lux and exposure) and how it relates to objective (as measured by actigraphy) and subjective (as measured by sleep diaries) nighttime sleep variables in older adults.

A secondary data analysis was conducted using two weeks of actigraphic and sleep diary data collected from 103 community-dwelling older adults (*M=72.81, SD=7.12*). Overall, all participants received greater than 3000 lux of light. Correlational analyses revealed that greater ambient light was significantly related to less subjective total wake time. Linear regression analyses revealed that ambient light accounted for a small amount of the variance in subjective total wake time (4.9%). Hierarchical regression analyses revealed that ambient light did predict a significant amount of the variance in sleep although not 'over and above' that accounted for by age, health, and daytime functioning. These findings demonstrate ambient light is related to sleep; however, not over and beyond other variables that are more commonly used in sleep research and assessment.

Several components of the ambient light–sleep relationship in older adults have been overlooked in previous research. The present study is innovative, because it is the first to: 1) examine ambient light's influence on *both* concurrently collected objective and subjective sleep; 2) implement a longer data collection period; 3) use a novel way to collect ambient; and 4) examine ambient light in the southeastern United States. Although the current study provides many innovations, many components of the ambient light-sleep relationship have yet to be explored (i.e., time of day of light and daytime activity). Considering that the current findings demonstrated that ambient light is related to sleep in older adults, although not over and beyond the other sleep-related variables examined, future research examining ambient light as a potential intervention for late-life insomnia appears warranted. In particular, such research should focus on subpopulations of older adults likely to receive much lower levels of ambient light than the sample of community-dwelling older Floridians examined in the present study (i.e., nursing home residents, older adults in more northern geographical locations).

CHAPTER 1
INTRODUCTION

A number of natural changes occur along with the aging process, many of which can lead to sleep disturbances and insomnia (Kamel & Gammack, 2006), defined as difficulty falling asleep, staying asleep, or poor quality (nonrestorative) sleep for at least one month (American Psychiatric Association, 2000). These problems have been associated with many ill effects such as impaired daytime functioning, increased napping, decreased quality of life, increased likelihood for accidents, high health care costs, difficulty with attention, memory, and response time as well as psychiatric diseases, especially depression and anxiety (Ancoli-Israel, 2005; Ancoli-Israel & Cooke, 2005; Leger, 2000; Walsh, 2004).

Fortunately, poor sleep is not a natural consequence of age. Instead, many age and non-age-related factors combine to affect sleep (i.e., declines in daytime functioning, and increases in pain, and health conditions) and contribute to sleep disruption in later life (Bliwise, 2004; Drewes, 1999; Drewes, et al., 2000; Foley et al., 1999; Gislason, & Almqvist, 1987; Mallon, et al., 2002; McCrae et al., 2003; Renko, et al., 2005; Schwartz, et al., 1999; Thorpy, 2004; Whitney et al., 1997; Wilcox, et al., 2000). Another factor that can affect sleep is the amount of ambient light received. Previous research has shown that overall ambient light relates to various aspects of *objective* sleep, including sleep consolidation and total wake time (Hood, 2004; Sakuai & Saski, 1998; Wallace-Guy, et al., 2002; Youngstedt, et al., 1999). However, very little research has examined the relationship between daytime ambient light exposure and *subjective* sleep. Similarly, very few studies have examined the light/sleep relationship in community-dwelling older adults (Shochat et al., 2000). Therefore, the purpose of this study is to examine the relationship between ambient light and sleep behavior in older adults.

The present study is innovative because it is the first to: 1) examine ambient light's influence on *both* concurrently collected objective and subjective sleep; 2) implement a longer data collection period (12 days) compared to previous studies (2–7 days only), thus providing a more representative view of older individuals' light exposure; 3) use a method to collect ambient light which includes duration and exposure; and 4) examine ambient light in the southeastern United States, a novel geographical location, which has unique conditions that influence light (i.e., milder winters allow individuals to spend more time outdoors, raising their light exposure.). Findings regarding the impact of ambient light on sleep could translate into empirically valid ambient light interventions to improve sleep in later life.

The subsequent chapters provide an overview of the relevant ambient light and sleep literature. Following this overview, the specific aims, hypotheses, measurements, statistical analysis, results, and discussion of the study's findings will be presented.

CHAPTER 2
REVIEW OF THE LITERATURE

The survival of most of earth's species, including humans, has depended upon adaptation to the 24-hour light/dark cycle which governs the planet. Sunlight plays a particularly important role in this adaptation, because it directly influences the endogenous circadian clock that maintains and organizes our daily biological rhythms, including the sleep-wake cycle. Although sunlight exerts the most powerful influence on the sleep-wake cycle, other sources of ambient light (i.e., artificial light sources) are influential as well. Considering that both physical and cognitive restoration occurs during sleep, a well-regulated sleep-wake cycle is essential for optimal functioning. Conversely, poor sleep is detrimental and has been associated with impaired daytime functioning, difficulty with attention, memory, and response time, increased napping, decreased quality of life, greater likelihood for accidents and psychiatric diseases, especially depression and anxiety (Ancoli-Israel, 2005; Ancoli-Israel & Cooke, 2005; Leger, 2000; Walsh, 2004). Although these consequences impact individuals of all ages, they are frequently more severe for older individuals because these diseases can increase the number of falls (Hill et al., 2007), the likelihood of institutionalization (Ohayon, Caulet & Lemoine, 1996), and the incidences of dementia diagnose (Kayukawa et al., 1998). Considering that sleep plays such a critical role in human functioning, it is imperative to study factors influencing sleep. Ambient light is one factor influencing sleep. As we age, both the amount of ambient light received and the quality of sleep are altered (Campbell et al., 1988; Swaab et al., 1985; Swaab et al., 1992). Therefore, ambient light has a unique relationship with older adults' sleep patterns. The impact of light on older adults' sleep patterns under controlled, laboratory conditions has been well-established (Ancoli-Israel et al., 2003; Campbell, Dawson, & Anderson, 1993; Loving et al., 2005; Youngstedt et al., 2005). However, the relationship between ambient light and sleep

and the factors influencing that relationship in community-dwelling populations has received less attention.

Ambient Light

Before examining the relationship between ambient light and sleep it is helpful to define ambient light. Ambient light refers to environmental illumination and includes both natural (i.e., sunlight) and artificial light sources (i.e., overhead fluorescent bulbs). Ambient light is considered to be the most influential regulator or 'zeitgeber' (German for time giver) of our endogenous circadian rhythms (Aschoff, 1960). When examining light, researchers employ a standard measurement called a lux, which is defined as the illumination from one candle one meter away. Indoor lighting typically ranges from 50-400 lux. Additionally, outdoor light typically ranges from 400 lux at sunrise/sunset to 100,000 lux at noon on an average day. Current literature holds that exposure to 1,000 lux is considered moderately bright light (Kohsaka et al., 1999), 2500-3000 lux is bright light (Lack & Wright, 1993; Youngstedt, Kripke & Elliott, 2001), and 10,000 lux is very bright light (Montgomery & Dennis, 2002). The distinction between moderately bright light, bright light, and very bright light is important given that lux above 2,500-3,000, or bright light, is required to entrain sleep changes (Lack & Wright, 1993; Youngstedt, Kripke & Elliot, 2002).

In order to gain a better understanding of ambient light's effects on sleep it is necessary to recognize the underlying mechanism of this process, namely circadian rhythms. Circadian rhythms are defined as the routine physical and mental changes that occur over the course of an approximately 24-hour day. Ambient light regulates our circadian rhythms as a result of its influence on the suprachiasamatic nucleus (SCN). Specifically, ambient light passes through a direct retina-hypothalamic tract (RHT) to the SCN, which is located in the anterior hypothalamus. The SCN, which is commonly referred to as our 'circadian clock' (Moore &

Eichler, 1972; Stephan & Zucker, 1972), maintains and organizes our physiological, hormonal, and behavioral rhythms. These rhythms temporally partition our environment into segments of approximately 24 hours and have allowed for adaptations to changes in our environment. Under normal exposure to 24-hour cyclic patterns in the environment (i.e., the earth's light/dark cycle), our circadian rhythms synchronize to exactly a 24-hour cycle.

Biological Underpinnings of the Ambient Light-Sleep Relationship

The circadian rhythm cycle is the biological mechanism underlying ambient light's affect on sleep. Evidence of the biological underpinning has been confirmed in animal models, and is shown in humans through ambient light's influence on shifts between wake and sleep and ambient light's ability to produce sleep phase adjustments.

Empirical Support in Animals

As previously mentioned, the ambient light-governed SCN is the mechanism that underlies the 24-hour circadian rhythm cycle and that controls behavioral rhythms such as the sleep-wake cycle. The function of the SCN as the 'circadian clock,' or circadian behavioral rhythms generator, is supported by combined lesion and transplantation studies (Ralph et al., 1990; Sujino et al., 2003). During these studies, both normal fetal SCN tissue and genetically mutant fetal SCN tissue were transplanted into previously SCN-lesioned animals. The particular genetic mutation used in these studies has been previous found to cause the absence of circadian rhythm behaviors, shown through a complete lack of sleep-wake patterns. After the transplantation, the normal fetal SCN tissue restored the circadian rhythm behaviors of the SCN-mutant animals and the SCN-mutant tissue caused the previously normal SCN-lesioned animals to no longer display circadian rhythms behaviors. In other words, the cells of the SCN region appear to determine the basic period of the endogenous circadian rhythm which controls behavioral rhythms such as sleep.

Under normal exposure to a 24 hour cyclic pattern in the environment (such as light and darkness), an organism's endogenous circadian rhythms, and thus behavioral rhythms such as sleep, synchronize exactly to the 24 hour cycle. However, when placed in constant darkness, organisms sift to 'free-running' circadian rhythms in which they are forced to rely only on endogenous cues (Zhang, et al, 2006). These free-running circadian rhythms may be shorter or longer than 24 hours and result in phase advances or phase delays in sleeping patterns. Therefore, light exposure is highly important in maintaining 24-hour rhythms.

Empirical Support in Humans

Studies in humans have further explored ambient light's influence through the SCN on sleep-wake behavioral rhythms. On a neural level, the SCN regulates a system of interconnected but neurochemically distinct cells dedicated to sleep functions, including the initiation and maintenance of arousal, rapid-eye-movement sleep (REMS) and non-REMS (Mistlberger, 2005). Ambient light exposure employs the SCN to induce shifts from sleep to wake and wake to sleep (Dijk & Lockley, 2002), as well as to adjust sleep phases. For example, ambient light received earlier in the day can result in a circadian phase advance shift, causing an individual to fall asleep and wake up at an earlier time. Conversely, ambient light received later in the day can result in a phase delay shift, causing the individual to fall asleep and wake up at a later time (Duffy, Zeitzer & Czeisler, 2006). Thus, in humans ambient light exposure can alter the timing of wake to sleep.

In humans, the measurement of ambient light is multifaceted. Given the various ways ambient light can be measured descriptions of different light measurements may clarify the following section. Light measures include below are as follows: the light mesor, mean amplitude, light acrophase, and threshold limits (Figure 2-1). The light mesor is the average value around which light and darkness oscillates. The light mesor represents the average amount of light received over a 24-hour cycle and includes both daytime and night time light. The use of the

mesor presents a problem, because it includes time when the participants were asleep or not receiving light. As a result, the mesor can not accurately reflect either daytime or nighttime light but rather creates a variable blending daytime and nighttime light which leads to a very low estimate of light as seen in Youngstedt and colleagues discussed below.

The mean amplitude (Figure 2-1) provides an average of each day's magnitude of the maximum disturbance in the medium (a degree near the middle of a range) during one wave cycle or the average of the highest light peaks for each 24-hour period. The acrophase (Figure 2-) is the time at which the peak of a rhythm occurs. Although innovative, the mean amplitude and acrophase are limited measures of light as well. The amplitude provides only the average of the peaks, so it is unable to distinguish duration and amount of time spent under this particular lux. Thus, an individual may be receiving light over a 2,500-3,000 lux threshold but may not be spending the necessary 30 to 240 minutes to induce changes in sleep (Campbell & Dawson, 1991; Campbell et al., 1993; Kohsaka et al, 1998; Lack & Scumacher, 1993; Sakakibara, et al, 1999). The acrophase is also limited as a measure because it only provides the time at which the amplitude occurs and does not contribute information about the duration that light was received.

The last light measurement is a threshold limit which assesses the mean number of minutes in 24 hours spent over a certain period of lux. The threshold approach examines light received during the active period of the day instead of over an entire 24-hour day because sunlight is generally the only light that reaches the minimum threshold of effective lux 2,500-3,000 lux. However, the threshold limits used in the Youngstedt and colleagues study, of which the largest was 2,000 lux, may be too low. Literature suggests that sleep is affected by a minimum of bright light at 2,500-3,000 lux (Lack & Wright, 1993; Youngstedt, Kripke & Elliot, 2002) and by the brightness recommended by researchers and clinicians for most people is very

bright light at 10,000 lux (Montgomery & Dennis, 2002). Consequently, Youngstedt and colleagues (1999) examined threshold limits that do not take into account bright light. Thus, an accurate evaluation of ambient light's effects may not have been ascertained. The threshold measure is also limited in that it only measures duration above a threshold and not duration though specific levels of lux. The current study employs a measure, Total Exposure, which gives such a measurement.

Empirical Support in Older Adults

Research in older adults has demonstrated ambient light's ability to induce sleep shifts in both the wake and sleep phases, the ability of controlled amounts of ambient light to improve sleep, and the association between low exposure to ambient light and increased sleep disturbances.

Experimental studies have been conducted in controlled settings in order to determine the effects of high intensity bright light on older adults. These bright light treatment studies revealed that light exposure does have an effect on specific nighttime sleep parameters in older adults. Specifically, studies have found exposure to bright light is associated with better objective sleep (Campbell & Dawson, 1991; Campbell et al., 1993; Kohsaka et al, 1999; Kohsaka et al., 2000; Lack & Scumacher, 1993; Sakakibara et al., 1999) and better subjective sleep (Kobayashi et al., 1999; Lack & Scumacher, 1993).

Conversely, older adults who receive insufficient ambient light exposure show sleep disturbance (Wallace-Guy et al., 2002). However, evidence of the relationship between insufficient ambient light exposure and poor sleep in community-dwelling older adults is scant (Shochat et al., 2000). To date, there have only been four studies (Hood, 2004; Sakuai & Saski, 1998; Wallace-Guy, et al., 2002; Youngstedt, et al.,1999), which have explored this relationship. Those four studies and their limitations are discussed in the following section. The following

section also makes distinctions between objective and subjective sleep. Objective sleep measures, unlike subjective sleep measures, do not include an individual's perception of sleep. Further discussion of this distinction may be found in the Measurements of Sleep section.

Naturalistic Studies of Ambient Light and Sleep in Older Adults

Sakuai and Saski (1998) studied older Japanese men and found associations between decreased light exposure and poor objective sleep. This study is noteworthy; because it was the first to provide baseline information for the averages of the entire rhythms of both sleep and light exposure (these averages are known as "mesors"; Figure 2-1). Unfortunately, interpreting the results of this study is complicated, because the researchers did not provide a clear definition of their light exposure variable. Additionally, there are limitations associated with using the mesor to measure sleep and light exposure. For example, the sleep mesor consists of both the sleep and the wake periods of the sleep cycle, and the light mesor consists of both the light and the dark periods of the daylight cycle. Thus, the sleep mesor is the average value around which sleep and wake oscillate. As a result, the sleep mesor contributes broad 24-hour information about the sleep-wake rhythm, but does not take into account idiosyncrasies of these rhythms. Idiosyncrasies of these rhythms include sleep fragmentation and nighttime awakenings, which often occur more frequently in older adults and only occur during the sleep section of the rhythm. Since these idiosyncrasies only occur during the sleep portion of the sleep mesor this information is averaged out and lost. The light mesor, as described above, is the average value around which light and darkness oscillates. As such, the light mesor measure is limited and likely results in a value that does not accurately reflect either daytime or nighttime light but rather creates a variable blending daytime and nighttime light. Additional limitations of the Sakuai and Saski (1998) study include a short data collection period of 3-4 days, absence of a subjective measure of sleep, and restriction of the sample to men.

Youngstedt and colleagues (1999) examined independently-living older adults in San Diego and found associations between decreased illumination levels, greater objective nighttime wakefulness, and longer objective sleep-onset latency. The study examined two groups: 1) those with complaints of insomnia or depression who were interested in a bright light treatment study and 2) 24 volunteers selected by phone. The researchers choose to use only objective measures of light and sleep for the 5-7 day data collection. The study looked at characteristics of sleep (i.e., wakefulness during the night and sleep onset latency) which is an improvement on the sleep mesor used in the Sakuai and Saski (1998) study. However, the study was limited in the selection of the light measures. The study used a 24-hour light mesor, as well as a measure of mean amplitude, an acrophase, and a threshold measure, which assessed the mean number of minutes in the 24 hours spent over 100, 200, 1,000, and 2,000 lux. To clarify the previously discussed results, the acrophase and amplitude were not significantly related to sleep, the 100 lux threshold was related to longer objective sleep-onset latency and the light mesor was associated with greater objective nighttime wakefulness, and longer objective sleep-onset latency. Although the mean amplitude, acrophase, and threshold measures are improvements in the measurement of light, the use of the mesor remains a limitation. As a result, the average mesor value of 447 lux in this study is very likely an underestimation of the amount of bright light received by the participants.

Wallace-Guy and colleagues (2002) studied postmenopausal women and found associations between greater overall ambient light and reduced objective time to fall asleep and reduced objective wake time during sleep (Wallace-Guy et al., 2002). The study used a convenience sample from the Women's Health Initiative Observational study and included women aged 51 to 81 (mean age = 66.7). Similar to the studies by Youngstedt and colleagues

(1999) and Sakuai and Saski (1998), Wallace-Guy and colleagues used the light mesor, which, as previously discussed, is likely an underestimate of the amount of bright light received. Other limitations of this study include the use of a female-only sample, a short seven day collection period, and only an objective measure of sleep.

Most recently, Hood (2004) examined light in Australian older adults and found that light exposure over 3000 lux was associated with better objective sleep consolidation. It is important to note that Hood's assessment of light (number of minutes spent over the light thresholds of 500 lux, 1,000 lux, and 3,000) represents an improvement over previous studies' threshold analyses because this approach examines light received over a bright light threshold of 3,000. As discussed above, bright light has been shown to affect sleep once it reaches 2,500-3,000 lux (Lack & Wright, 1993; Youngstedt, Kripke & Elliot, 2002). As discussed above, the use of thresholds to measure light, although an improvement over the mesor, does not account for a full picture of the overall total exposure to light received by an individual. The overall total exposure provides an exact measurement of the duration of the amount of light received.

Hood's study was innovative in that the assessment of the relationship between ambient light and sleep included both objective and subjective measures of sleep. Hood used nocturnal immobility as a measure of objective sleep. Nocturnal immobility is defined as the number of zero-mobility epochs (epoch = a 16 second interval) and provides an indication of sleep consolidation (i.e., the extent to which sleep is not interrupted by bouts of wakefulness). Subjective sleep was measured using the Pittsburgh Sleep Quality Index (PSQI; Buysse et al., 1989), which is a retrospective, self-report questionnaire that assesses sleep quality and disturbance over a one-month period. Although the inclusion of a subjective sleep measure was innovative, the PSQI provides only a global measure of sleep quality. Additionally, the PSQI is

a retrospective measure and, therefore, is subject to recall bias. Another limitation of this study is that Hood was not able to make any direct objective versus subjective sleep comparisons, because the objective and subjective sleep variables covered different time periods (i.e., a 3 day period for nocturnal immobility versus the past 30 days for the PSQI).

Sleep Measurement

As demonstrated above, most of the research on ambient light's effects on sleep in older adults has concentrated on the relationship between ambient light and objective sleep. However, the addition of subjective sleep, as seen in the aforementioned Hood study, is extremely important for a myriad of reasons. These include discrepancies in objective and subjective measurement, subjective measurement's inclusion of the perception of sleep, and the implication of this inclusion for the current study.

There are well-documented discrepancies between subjective and objective measurements of sleep (Broman et al., 1992; Kushida et al., 2001; Morin, 2003; Vignola et al., 2000). More specifically, actigraphy has been found to significantly overestimate total sleep time and sleep efficiency compared to subjective sleep measures (Kushida et al., 2001). Additionally, subjective measurements have been found to be less sensitive than actigraphy, a measure of objective sleep, for documenting nighttime awakenings (Broman et al., 1992; Kushida et al., 2001; Vignola et al., 2000). These discrepancies stem from the fact that objective and subjective assessments measure different aspects of sleep experience (Coates et al., 1982).

Objective (Actigraphy) Measurement of Sleep

Prior to Hood's (2004) study, researchers focused solely on objectively-measured sleep when examining the relationship between ambient light and sleep in older adults. Objective sleep measurements allow for the observation of sleep behaviors without inclusion of an individual's sleep perceptions. Thus, objective sleep measurements do not rely on the perception

of sleep and thus do not experience decay due to recall. Decay due to recall involves misestimating the length of time taken to fall asleep or the number and length of awakenings during the night due to recording the information the following morning. Thus, objectively measured sleep can detect the influence of ambient light on sleep behaviors and has implications for the underlying biological nature of this relationship.

Actigraphy is the most commonly used objective measure. An actigraph is a small lightweight, limb-worn device that contains an accelerometer that allows it to detect activity (i.e., limb movements). The activity information is used to determine whether an individual is asleep or awake (little/no movement = sleep, movement = wake). Another objective sleep measure, polysomnography (PSG or sleep EEG), is generally considered to be the 'gold standard' in the objective assessment of sleep; however, it is too expensive for naturalistic, longitudinal data collection. Thus, actigraphy is the preferred method for such data collection for a number of reasons including: it is less expensive than PSG; it records sleep in participants' home environments; it provides concurrent ambient light information (on models that are equipped with a light sensor); and it distinguishes between sleep/wake cycles (Ancoli-Israel et al., 2003). Additionally, because participants can wear an actigraph while engaging in their normal daily activities, actigraphy can be used throughout both day and night, providing data otherwise unobtainable with night-only PSG recordings (Ancoli-Israel et al., 2003). Currently, there are only 2 available actigraphs Actiwatch-L® (Mini Mitter, Inc) and Actillume® (Ambulatory Monitoring, Inc), which are capable of collecting both activity and light information. Unfortunately, direct comparison of the light analysis properties of these two devices has not yet been conducted, so reliability comparisons cannot be reported. However, comparisons of these devices in terms of their ability to record sleep properties have shown that they provide similar

overall performance (Benson et al., 2004). The present study utilizes the Actiwatch-L® (Mini Mitter, Inc) to measure both light and objective sleep over a 12 day period in community-dwelling older adults.

Subjective Measurement in the Study of Sleep

Even though objective sleep assessments provide important information regarding the ambient light and sleep relationship; this relationship does not occur in isolation. An individual's subjective perception of sleep, which is removed from measurements of objective sleep, may also alter the ambient light-sleep relationship. An individual's perception of sleep is extremely important given that those who sleep poorly may have developed cognitive processes which result in perceived poor sleep when they sleep well and overestimation of the impact of actual sleep loss (Harvery, 2002; Semler & Harvey, 2005). These individual's perceptions and overestimations of poor sleep are associated with impaired daytime functioning (i.e., excessive worry, distress, and fatigue) as well as a tendency to engage in behaviors (i.e., staying in bed to catch up on sleep) that may alter the amount of ambient light received (Morin, 1993; Semler & Harvey, 2005). It appears that the actual amount of sleep, as obtained by objective measures, is not only a different aspect of the sleep experience but also differently affects daytime functioning and behaviors. In relation to the ambient light and sleep relationship individuals that engage in altered daytime behaviors such as spending time in bed to catch up on sleep may be increasing exposure to artificial light or choosing to spend more time without receiving any exposure to sunlight at all. This adjustment in ambient light could mean that individuals are not receiving the lux needed to produce phase shift changes in sleep.

Poor perceptions of sleep tend to be chronic in older adults. Insomnia, which is defined as subjective complaints of poor sleep (i.e., difficulty falling asleep, staying asleep, or poor quality sleep) for at least six months (American Psychiatric Association, 2000), tends to last an average

of 7 to 12 years in older adults (McCrae, 2003; McCrae, 2006)). It is not only the chronic nature of this disorder that is a concern in older adults, but also the prevalence rate, which more than doubles from 1-10% in the general adult population to 25% in the older adult population (American Psychiatric Association, 2000). Other studies show even higher prevalence rates in older adults, up to 50%, for poor sleep complaints, which can only be measured subjectively (Vitiello, 2000). In fact, insomnia is the most common sleep disturbance affecting older adults (Kamel & Gammack, 2006).

The issue of high prevalence rates and the chronic nature of sleep disorders in older adults are made salient when examining the consequences of these sleep disorders. Poor sleep perceptions, particularly in the case of insomnia, have been associated with impaired daytime functioning, difficulty with attention, memory, and response time, increased napping, decreased quality of life, greater likelihood for accidents and psychiatric diseases, especially depression and anxiety (Ancoli-Israel, 2005; Ancoli-Israel & Cooke, 2005; Leger, 2000; Walsh, 2004). The consequences for the individual are compounded by the economical consequence of insomnia. The estimated direct costs of insomnia are $13.9 billion annually (Walsh, 2004). Consequently, it is of importance both for the individual and for society to discover how perception of sleep affects the ambient light and sleep relationship in older adults.

Given these consequences, which may be uniquely linked to subjective sleep perception, the addition of subjective measurement to the study of the ambient light and sleep relationship is warranted. Previous inclusion of a subjective sleep measure (occurring in the Hood [2004] study) was limited in that the measure selected was a monthly retrospective measure of subjective sleep that was not directly comparable to the objective sleep measurement. The current study addresses this limitation by measuring objective and subjective sleep concurrently over 12 days. Given that

sleep has been shown to fluctuate considerably from night to night, concurrent measures as well as an increased data collection period are important when assessing both objective and subjective sleep.

Sleep diaries are a measurement of subjective sleep that have become a staple of sleep assessment for a myriad of reasons including: practicality and ease of training for home use; clinical utility for capturing change over time; reliability for assessing sleep patterns when compared to PSG; validity in the quantification of the sleep complaint; representation of qualitative information; measurement of daytime sleep activities (napping); and relevance for monitoring treatment progress (Lichstein & Morin, 2000). Sleep diaries are the recommended method for assessing insomnia and are more widely used in research and practice than actigraphy (McCrae et al., 2005). Therefore, sleep diaries were employed to measure subjective sleep in the current study (Lichstein et al., 1999).

Factors Influencing the Older Adult Ambient Light/Sleep Relationship

Examining the impact of ambient light on the sleep-wake cycle in older adults is particularly challenging because endogenous age-related changes in the SCN combine with other age-related changes (both physical and mental) and the weakening of exogenous cues to affect the sleep-wake cycle.

Endogenous Factors

The ability of light to regulate the sleep-wake cycle decreases with age. This can be attributed to several factors, including decreased neuronal activity of the SCN, decreased ophthalmic functioning, and poor physical and mental health.

As individuals age, their ability to synthesize vasopressin, one of the main peptides in the SCN, is reduced. As a result, there is an overall decrease in the neuronal activity of the SCN (Swaab et al., 1985; Swaab et al., 1992). As a result, both the amplitude and the length of the

sleep-wake cycle decline. Additionally, reduced SCN activity is associated with an increased propensity for internal desynchronization of the sleep-wake cycle with other circadian rhythms (Brock, 1991; Monk, 1989; Richardson, 1990; Touitou & Haus, 1992). When internal desynchronization of the sleep-wake cycle occurs, the sleep-wake cycle is no longer in harmony with other circadian rhythms, such as locomotor activity (skeletal and muscular movement), body temperature, and feeding rhythms. This internal desynchronization results in various consequences for physiological and psychological well being, such as sleep disorders, gastrointestinal complaints, respiratory problems, and psychological disturbance (Aanonsen, 1959; Akerstedt & Gillberg, 1981; di Pietralata, et al., 1990; Moore-Ede, et al., 1982; Reinberg & Smolensky, 1992; Verhaegen, et al., 1981). Thus, as individuals age, ambient light's ability to affect sleep and optimal functioning may be diminished through an altered SCN.

Other age-related endogenous changes also affect the regulation of the sleep-wake cycle. Ophthalmic functioning, for example, decreases with age. Specifically, there is a reduction in pupil diameter as well as a yellowing of the lens (Hughes & Neer, 1981; Teresi et al., 1994) which attenuates light transmission though the eye. The pigmentation of the lens specifically decreases shortwave light transmission to the retina. The circadian clock mechanism is most sensitive to shortwave or blue light, so decreases in transmission of this type of light may be particularly detrimental. Thus, with age, a reduction in various ophthalmic functions combines with an altered SCN to diminish ambient light's ability to regulate the sleep-wake cycle.

Physical Health

In addition to decreased ophthalmic functioning and an altered SCN, aging is also associated with an increase in medical and health conditions. Previous research demonstrates a relationship between increased chronological age and decreased organ functioning (Durakovic & Misigoj-Durakovic, 2006). Poor health in general may also be a factor influencing the ambient

light and sleep relationship. Not only do those with poorer health spend less time outdoors engaging in activity, thus decreasing possible exposure to ambient light, but poor health has been associated with poor sleep. In fact, many medical conditions contribute to objective sleep disruption in later life, including osteoarthritis (Wilcox, et al., 2000), rheumatoid arthritis (Drewes, et al., 2000), and neurological disorders such as Parkinson's disease (Thorpy, 2004) and Alzheimer's disease (Bliwise, 2004). Medical conditions such as coronary artery disease (Mallon, et al., 2002) and type 1 and type 2 diabetes mellitus (Renko, et al., 2005; Gislason, & Almqvist, 1987) can also contribute to subjective sleep disruptions in later life. Due to medical conditions' known impact on sleep and the increase in medical conditions with increased age, it is important to control for medical conditions when examining the ambient light and sleep relationship in older adults.

Mental Health

Poorer daytime functioning is another factor influencing the ambient light and sleep relationship. Associations have been found between individuals' perception of sleep and impaired daytime functioning (i.e., excessive worry, distress, and fatigue) as well as a tendency to engage in behaviors (i.e., staying in bed to catch up on sleep) that will reduce the amount of ambient light received and impact future sleep (Morin, 1993; Semler & Harvey).

Factors affecting daytime functioning such as depression and anxiety may uniquely affect the ambient light and sleep relationship. An estimated two million older adults have a depressive illness and another five million may have depressive symptoms (Narrow, 1998). Additionally, anxious and depressive symptoms are often comorbid in all age groups (Feldman, 1993; Master & Cloninger, 1990) and may be even more correlated in older adults (Lawton, Kleban, & Dean, 1993). Previous research has shown associations between higher levels of depressive symptomatology and low exposure to ambient light (Espiritu et al., 1994; Jean-Louis et al., 2005;

Kripke et al., 2004; Oren et al., 1994; Youngstedt et al., 1999). Symptoms of depression include psychomotor retardation, fatigue, and diminished interest or pleasure in all, or almost all activities. Those experiencing these symptoms may spend less time active and outdoors, thus decreasing possibly exposure to ambient light. There is also evidence to support the association between depression, anxiety, and insomnia symptoms (Foley et al., 1999; McCrae et al., 2003). Thus, due to the effects of depression and anxiety on sleep, it is important to control for these particular daytime functioning measures in order to ascertain ambient light's effect on sleep above and beyond these daytime functioning variables.

Fatigue is another specific daytime functioning factor which affects the ambient light and sleep relationship. Fatigue, similar to poor health, may inhibit an individual's outdoor time through lower activity, thus decreasing exposure to ambient light. The lower activity level brought on by fatigue may also contribute to poor sleep. This is shown by previous research finding an association between fatigue and insomnia symptoms (Whitney et al., 1997). Thus, just as recommended for the daytime functioning variables of anxiety and depression, it is important to control for fatigue in order to ascertain ambient light's effects on sleep above and beyond fatigue.

Exogenous Factors

In addition to the endogenous reduction in SCN efficiency, ophthalmic function, and other age-related changes in both physical and mental health, research has shown that exogenous cues, such as lower exposure to ambient light and lower physical activity, influence circadian rhythm regulation.

In fact, older Americans' light exposure, an exogenous cue, might be insufficient for maintaining optimal circadian rhythm regulation. One study found that on average, independent older adults receive only one hour of natural light a day, or only 59 minutes above 2000 lux

(Campbell et al., 1988). Indoor lighting typically ranges from 50-400 lux and outdoor light typically ranges from 400 lux at sunrise/sunset to 100,000 lux at noon on an average day. Therefore, according to the study by Campbell and colleagues (1988), older adults are experiencing decreased exposure to outdoor ambient light.

An additional exogenous factor includes lifestyle changes that may reduce bright light exposure. Older adults tend to engage in less vigorous daily physical activity (Van Someren et al., 1994), which can be related to less outdoor activity.

In summation, both endogenous and exogenous cues affect light and the lifestyle choices we make as we age. Thus, in order to fully understand the relationship between sleep and light in older adults, a naturalistic approach that captures older adults' sleep patterns and light exposure during their normal daily lives is absolutely essential.

Summary of the Innovations of the Present Study

Previous research has examined the connection between objectively measured sleep and ambient light. However, gaps still remain in the existing research. The current study holds specific innovations over previous research. These innovations include the inclusion of a subjective measurement of sleep, use of an extended measurement period, use of a novel measure of light, and conducting observations in a new geographical area.

The first innovation of the current study is the use of a subjective, as well as an objective, in-depth analysis of the relationship between light and sleep in a sample of older adults. As described more fully above, there are well documented discrepancies between subjective and objective sleep. These discrepancies stem from the fact that objective and subjective sleep measures assess different aspects of sleep. Previous research through both controlled and naturalistic studies has shown ambient light's relationship to objective sleep. However, the objective sleep and ambient light relationship fails to take into account individual's perception of

sleep, which is used in diagnosing sleep disorders prevalent in older adults. Thus, the combination of measures of both objective and subjective sleep allow researchers the opportunity to more fully understand the ambient light-sleep relationship in older adults by taking into account the perception of sleep.

The second innovation of the present study involves significantly extending the measurement periods used in previous research. As discussed earlier, existing studies have examined ambient light and sleep over periods ranging from 2-7 days. The present study examines ambient light and sleep over a period of almost two weeks. The two week data collection is almost twice as long as the longest period of data collection in previous studies. This is of particular importance given that sleep and light exposure show variability across time. Thus, the extended data collection period in the present study will provide a more representative view of the amount of ambient light and sleep obtained by older individuals because it includes more instances (days) during which to account for variability.

Another innovation of the current study is the method of measurement of ambient light. Previous research has used the light mesor, mean amplitude, acrophase, and threshold measurements to examine light. As discussed above, the light mesor represents the average amount of light received over a 24-hour cycle and includes both daytime and nighttime light. The mesor presents a problem, because it includes time when the participants were asleep or not receiving light. As a result, the mesor leads to a very low estimate of light. The mean amplitude provides the average of the highest light peaks for each 24-hour period and the acrophase is the time at which this peak occurs. These measurements are limited due to an inability to distinguish duration, amount of time, spent under this particular lux. As a result, individuals may be receiving enough light; however, they may not be receiving light for a long enough duration to

induce changes in sleep. The threshold approach does provide duration, minutes received over a threshold set by the researcher; however, minutes over a certain threshold does not provide a full picture of the light received. Although the information provided allows for an idea of the duration of effective light, it does not allow for an exact measurement of the duration of the amount of light received. The current study employs a measure, Total Exposure, which provides such a measurement.

Finally, the present study extends our knowledge of the ambient light and sleep relationship to a new geographical area - the southeastern United States. Previous studies have collected data in Japan, Australia, and San Diego. Geographic location, seasons, and behavior (e.g. choice of indoor vs. outdoor environment) have been found to strongly influence human ambient light exposure (Cole et al., 1995). Data collection in the southeastern United States is important due to its unique regional weather conditions, as well as the region's prevalence of older adults. These regional conditions include the seasonal and geographic circumstances (average annual temperature of 68.4°F) that culminate in milder winters. Mild southeastern winters may cause older adults to increase the amount of daytime hours spent outdoors throughout the year and thus increase exposure to light.

In conclusion, the present study addresses the limitations of and extends previous research, by naturalistically observing the relationship between ambient light and both *objective* and *subjective* sleep over a two week period in community dwelling older individuals in the southeastern United States.

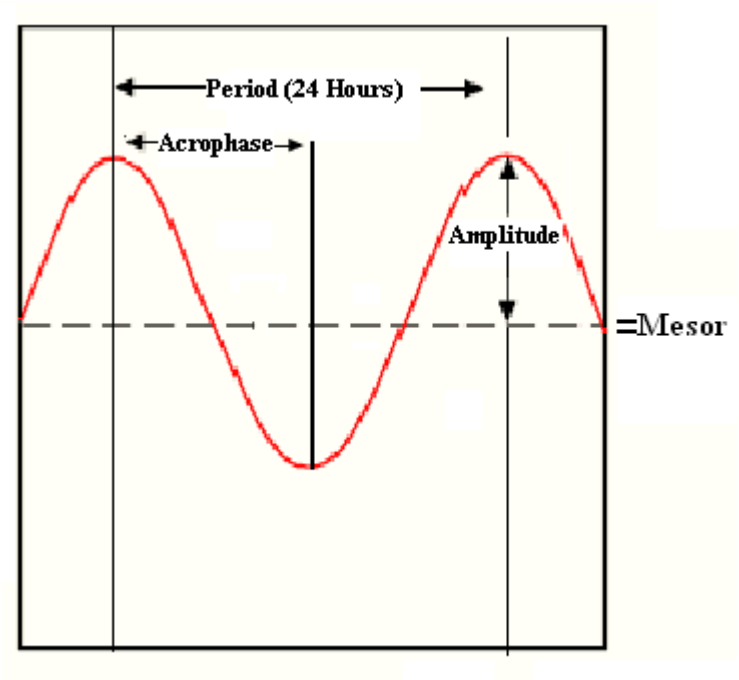

Figure 2-1. Visual representation of Mesor, Acrophase and Amplitude.

CHAPTER 3
PURPOSE AND HYPOTHESES

The general goal of the current study is to examine the relationship between ambient light and sleep behavior in older adults. This study's 3 specific aims are provided below:

Specific Aim 1: to Explore the Relationships between Age, Health, Daytime Functioning, Ambient Light, and Sleep (Objective and Subjective).

Hypothesis 1-Relationships between the Age, Health, Daytime Functioning, Ambient Light, and the Sleep Variables:

Age will be negatively correlated with objective and subjective sleep. Specifically increased age will be positively correlated to total wake time$_{o/s}$ and negatively correlated to total sleep time$_{o/s}$. Poorer health will be associated with poorer objective and subjective sleep. Specifically, number of medical conditions will be positively correlated to total wake time$_{o/s}$ and negatively correlated to total sleep time$_{o/s}$. Measures of daytime functioning, including depression, anxiety, and fatigue, will be associated with both objective and subjective sleep. Specifically, these daytime functioning measures will be negatively correlated with total sleep time$_{o/s}$ and positively correlated to total wake time$_{o/s}$. Greater ambient light (total exposure) will be associated with better objective and subjective sleep. Specifically, ambient light (total exposure) will be negatively correlated with total wake time$_{o/s}$ and positively correlated with total sleep time$_{o/s}$. Additional regression analyses will then be performed on all variables that showed significant bivariate correlations.

Specific Aim 2: to Examine the Amount of Variance in Sleep Accounted for by Ambient Light.

Hypothesis 2

Ambient light is expected to account for a significant amount of the variance in both objective and subjective sleep. Specifically, greater ambient light (total exposure) will positively

predict total sleep time$_{o/s}$, and negatively predict total wake time$_{o/s}$. We will perform linear regression analysis on all variables that showed significant bivariate correlations in Aim 1. Aim 2 will examine how much variance in sleep is accounted for by ambient light alone. This analysis will allow for a comparison to the results of Aim 3, which examines how much variance in sleep is accounted for by ambient light when the other variables that were associated with sleep in Aim 1 are also considered.

Specific aim 3: What Are the Incremental Contributions of Age, Health, Daytime Functioning, and Ambient Light (in that Order) to the Prediction of Sleep?

Hypothesis 3

Considering the effects of ambient light, medical conditions, depression, anxiety, and fatigue on sleep, it is important to control for these particular daytime functioning factors in order to ascertain ambient light's effect on sleep 'over and above' these variables. Hierarchical block regression analyses will be performed for all variables that showed significant bivariate correlations in Aim 1. It is expected that ambient light will account for a significant increase in the amount of variance in sleep (both objective and subjective) 'over and above' that accounted for by age, health, and daytime functioning.

CHAPTER 4
METHODS

Participants and Procedure

A secondary data analysis was performed with data previously collected by McCrae and colleagues (2005). A convenience sample of 116 adults, aged 60 years and older, residing in North Central Florida were recruited through media advertisements, community groups, and flyers to participate in a study of sleep patterns in older adults. Interested individuals were screened in two phases: a brief telephone interview (15-20 minutes) followed by a 1-1.5 hr in-person interview conducted either in the individual's home (76%) or at a local continuing care retirement center (24%). Exclusionary criteria included: a. younger than 60 years; b. self-report of sleep disorder diagnoses other than insomnia (e.g., sleep apnea, narcolepsy); c. self-report of symptoms suggestive of other sleep disorders (e.g., heavy snoring, gasping for breath, leg jerks, daytime sleep attacks); d. severe psychiatric disorders (e.g., thought disorders, depression); e. cognitive impairment (i.e., scoring in the impaired range on 3 or more subtests of the Cognistat (Kiernan et al., 1987) ; f. psychotropic or other medications (e.g., beta-blockers) known to alter sleep; and g. medical conditions that impaired ability to be completely independent in normal daily functions. Thirteen individuals were ineligible for reasons including age, dementia diagnosis, medication, sleep apnea diagnosis, and suspected sleep apnea. Thus, the final sample consisted of 103 participants. All were living in their own homes during the study. The majority of the sample was Caucasian (96%), female (64%), and married (71%). See Table 4-1 for other sample characteristics.

All participants read and signed an informed consent form approved by the University of Florida Institutional Review Board. Afterwards, the Cognistat, a sleep history interview, and the demographics and health survey were administered and both the sleep diaries and the Actiwatch-

L® were explained to the participants. At the end of the first week of the study, the sleep diaries were collected from the participants, and data was downloaded from the Actiwatch-L®. Then, at the end of the second week, the sleep diaries and Actiwatch-L® data were collected and the Beck Depression Inventory-Second Edition (BDI-II, Beck, Steer & Garbin, 1996), State-Trait Anxiety Inventory-Form Y1 (STAI-Y1, Spielberger et al., 1983), and the Fatigue Severity Scale (FSS, Krupp et al., 1989) were administered.

Measures

Objective Sleep

This method involved the placement of the Actiwatch-L®, a device roughly resembling a wrist watch, on the non-dominant wrist. The Actiwatch-L®, which monitors gross motor activity, consists of an omnidirectional, piezoelectric accelerometer with a sensitivity of ≥0.01 g-force. The accelerometer located within the device collected peak value samples 32 times per second for each 30 second epoch and then compared across multiple samples to assess whether the threshold for wake or sleep activity was met (Mini Mitter, 2001). Each epoch's peak activity count (i.e., the sum of the peak values) was then downloaded to a PC and analyzed by the software Actiware-Sleep vol. 3.0 (Mini Mitter, 2001) using a validated algorithm to identify the epoch as sleep or wake (Oakley, 1997). The software provided three default sensitivity settings (high, medium, low). We utilized high sensitivity because it provides excellent correlation with PSG for total sleep time (.95) in healthy older adults (Colling et al., 2000) and for total sleep time (.73) and sleep onset latency (.93) in individuals with insomnia (Cook et al., 2004). The threshold for high sensitivity is 20 activity counts. If the peak activity count for an epoch was > 20, it was scored as wake. If the peak activity was, < 20, the determination of sleep/wake was made by examining the activity in the surrounding 2 minutes using the following equation:

Total Activity Epoch A

$$= E_{A-4}(.04) + E_{A-3}(.04) + E_{A-2}(.20) + E_{A-1}(.20)$$

$$+ E_{A}(2) + E_{A+1}(.20) + E_{A+2}(.20) + E_{A+3}(.04) + E_{A+4}(.04),$$

where A = activity count for the epoch being scored, and $E_{A+/-1-4}$ = activity count in adjacent epochs. If Total Activity Epoch A (i.e., weighted sum of activity counts) exceeded the threshold of 20, then Epoch A was scored as wake; otherwise, it was scored as sleep. In summary, wrist movement was collected, downloaded into a computer program and analyzed to determine if an individual was experiencing wake or sleep for each 30 second epoch. From this movement data, a computer program mathematically assigned a time period as either wake or sleep. The information collected was used to calculate the following sleep variables: 1. total wake $time_o$ [TWT_o]: sum of all wake epochs within the sleep period; and 2. total sleep $time_o$ [TST_o]: sum of all sleep epochs within the sleep period. Means were computed for each variable for the 12 days for which there was both ambient light and concurrent sleep information. Actigraphy has valid criterion-validity when compared to PSG (.80) and high test-retest reliability (0.92; Ancoli-Israel et al., 2003). There were no equipment failures and data loss was minimal. In regards to compliance, a few participants (n = 3) removed their Actiwatch-L® during the day. Although the duration was less than 3 hours, and all participants replaced the watch several hours before bedtime, these days were removed from the analysis. The removal of this data was due to the need to analyze light data collected during the day. It reduced the data of these participants to 11 days of data instead of 12. A few other participants (n = 3) left their watches off for an entire day (24 hours). These participants wore their watches and completed their sleep diaries an additional day immediately following the study period (e.g., day 15). This additional day was substituted for the watch-off day when averaging the daytime variable of ambient light. Finally, a single participant neglected to wear the watch during week 2, and was dropped from the analysis.

Thus, for all but three participants, as described above, we have concurrent sleep diary and actigraphy data for 12 days.

Subjective Sleep

Sleep dairies (Lichstein et al., 1999) were completed each morning for 12 consecutive days and provided the following variables: 1. total wake time$_s$ [TWT$_s$]: time spent awake from entrance into bed to time out of bed in the morning; and 2. total sleep time$_s$ [TST$_s$]: computed by subtracting total wake time from time in bed. The mean value for each variable over the 12 day recording period was calculated. Compliance with diary completion was exceptionally high. Of the 2,472 possible data cells (2 sleep diary variables x 12 days x 103 participants), only 70 were absent (2.83%).

Ambient Light

The Actiwatch-L® (Mini Mitter Co. Inc) also provided data on ambient light. The Actiware Sleep v. 5.0 light analysis program (Mini Mitter, 2005) was used to examine ambient light. The start of the daytime period was defined as reported out-of-bed time and the end was defined as the reported in-bed time according to the sleep diaries. The actogram was also examined to detect any inconsistencies in reported in and out-of-bed times and activity levels. When inconsistencies were detected, they were generally minor (i.e., 45 minutes on average, range 10 – 60 minutes). In those cases, the in and out-of-bed times were adjusted by the researcher to match the actogram. Similar to the nighttime sleep analysis, a 30 second epoch was used. The light variable provided by the software was total exposure [TotExp]: total daytime exposure in lux multiplied by 0.5 minutes. This light variable provides the amount of lux received each 30 second epochs multiplied by the number of 30 second epochs the individual was exposed to the light.

Health and Daytime Functioning

Demographics and Health Survey

(Lichstein et al., 2003) is a two-page questionnaire with 13 items on demographics, sleep disorders symptoms, physical health, and mental health. For the purpose of this study, one item was taken from the demographics and health survey - medical conditions. Medical conditions were defined as the number reported from the following list: heart attack, other heart problems, cancer, AIDS, hypertension, neurological disorder (seizures, Parkinson's), breathing disorder (asthma, emphysema, allergies), urinary problems (kidney disease, prostate problems), diabetes, pain (arthritis, back pain, migraines), and gastrointestinal disorders (stomach, irritable bowels, ulcers, gastric reflux).

Beck Depression Inventory-Second Edition

(BDI-II; Beck, Steer & Brown, 1996) is a 21-item measure assessing the severity of depressive symptoms. Respondents were asked to describe themselves based on the previous two weeks. The 21 BDI-II items are scored on a 4-point scale with item scores ranging from 0-3 and total scores range from 0-63. The BDI-II has demonstrated sufficient internal consistency reliability (.90) and concurrent validity (.69 - .76) The BDI-II total scores ranging from 0 to 13 represent 'minimal' depression; from 14 to 19 represent 'mild' depression; from 20-28 represent 'moderate' depression; and from 29 to 63 represent 'severe' depression (Beck, Steer, & Brown, 1996).

Stait-Trait Anxiety Inventory – Form Y1

(STAI-Y1; Spielberger et al., 1983) contains 20 self-descriptive statements indicating how the respondent felt "right now, at this moment" on a 4-point scale ranging from 1 (not at all) to 4 (very much so). Total scores range from 20 to 80. STAI-Y1 demonstrates test–retest reliability exceeding .7 and reliably distinguishes patient and normal groups, higher scores

indicate greater maladjustment (Novy, et al., 1993; Spielberger et al., 1983). Sample items include “I feel at ease” and “I feel upset”.

Fatigue Severity Scale

(FSS; Krupp et al., 1989) is a 9-item questionnaire used to measure subjective severity of fatigue. The respondents were asked to indicate agreement with questionnaire items on a 7-point scale (1 = strongly disagree to 7 = strongly agree). Responses were averaged across the 9 items, yielding a possible score range of 1 to 7. Higher scores indicate higher levels of fatigue. The FSS showed high internal consistency (.88; Laberge et al., 2005), taps multiple dimensions and estimates general fatigue (Schwartz et al., 1993) and appears to measure fatigue separate from daytime sleepiness (Lichstein et al., 1997).

Statistical Analysis

Bivariate correlations were used to explore the relationships between ambient light, age, health, daytime functioning, and sleep (objective and subjective). Next, two sets of regression analyses were performed based on the resulting associations between the variables of interest identified in the bivariate correlations. First, linear regressions were conducted to examine the amount of variance in sleep accounted for by ambient light alone. Second, hierarchical multiple regression analyses were conducted to determine the incremental contributions of age, health, daytime functioning, and ambient light (in that order) to the prediction sleep. The incremental contribution of ambient light ‘over and above’ other variables routinely used in the assessment of sleep was of primary interest.

Table 4-1. Sample Characteristics

		Total Sample *N* = 103 *Mean* (*Standard Deviation*)
Age		72.90 (6.86)
Education (years)		16.16 (3.02)
Conditions[1]		2.00 (1.59)
Daytime Functioning		
FSS		3.45 (1.42)
STAI		39.98 (8.55)
BDI-II		5.28 (4.75)
Sleep Variables (minutes)		
TST_s		414.87 (59.63)
TWT_s		50.38 (36.68)
TST_o		392.16 (50.91)
TWT_o		77.32 (29.14)
Ambient Light, lux X .5 minutes		
TotExp		1064661.42 (690949.85)
TotExp Percentiles	25	477272.70
	50	909545.75
	75	1475993.00

Note. TST=Total Sleep Time, TWT=Total Wake Time, FSS= Fatigue Severity Scale, STAI= State-Trait Anxiety Inventory, BDI-II=Beck Depression Inventory-Second Edition, TotExp= Total Exposure.

[1]Total number of medical conditions: Participants were asked to indicate whether they had experienced each of the following conditions: heart attack, other heart problems, cancer, AIDS, hypertension, neurological disorder, breathing disorder, urinary problems, diabetes, pain and gastrointestinal disorder. This variable reflects the total number of these conditions reported from this list.

Note: Subscript ‘s’ denotes subjective sleep and “o” denotes objective sleep variables.

CHAPTER 5
RESULTS

The main objective of this study was to examine the relationship between ambient light and sleep in older adults. Each of the study's three specific aims and their associated results are presented below:

Specific Aim 1: to Explore the Relationships between Age, Health, Daytime Functioning, Ambient Light, and Sleep (Objective and Subjective).

Before analyzing these relationships, each variable was examined to determine whether or not it conformed to a normal distribution (see table 4-1). TotExp, TST_o, and TST_s contained one outlier each and TWT_s contained two outliers. Thus, the strategy that was adopted to correct for these deviations from normality was to replace these two cases with a value equal to the mean plus two standard deviations (Field, 2005). Bivariate correlations were conducted to examine the relationships of TotExp, Age, Health conditions, FSS, STAI and BDI-II and these TWT_s, TST_s, TWT_o, and TST_o sleep variables (Table 5-1).

As expected TotExp was significantly negatively associated with TWT_s. As hypothesized health conditions, FSS, and BDI-II were significantly positively associated with TWT_s and significantly negatively associated with TST_s. Surprisingly, TotExp was not significantly associated with TST_s, TWT_o, and TST_o.

Specific Aim 2: to Examine the Amount of Variance in Sleep Accounted for by Ambient Light.

Linear Regressions

The second goal of the study was to determine how much variance in sleep is predicted by ambient light alone. A linear regression analysis was conducted on Total Exposure and the significant correlated sleep variable (Table 5-1). Thus a linear regression analysis was conducted between TotExp and TWT_s, to examine how much variance in subjective sleep is accounted for

by ambient light. The linear regression analysis revealed that TotExp significantly predicted subjective total wake time. Specifically, TotExp significantly predicted TWT_s, accounting for 4.9% of the variance ($\beta = -.22$, $p < .05$). The effect size of .22 is considered a small effect (Cohen, 1988a, 1992b).

Specific aim 3: What Are the Incremental Contributions of Age, Health, Daytime Functioning, and Ambient Light (in that Order) to the Prediction of Sleep?

Hierarchical Block Regressions

The third goal of the study was to first determine the incremental contributions of age, health, daytime functioning, and ambient light, in that order to predict sleep. Ambient light was of particular interest in the study, so its incremental contribution to sleep 'over and above' that of demographics, health, and daytime functioning was of particular interest. A hierarchical block regression analysis was preformed on only significant variables (Table 5-1). Thus a hierarchal block regression analysis was conducted on TWT_s to examine how much variance in sleep is accounted for by health, daytime functioning, and ambient light. All predictor variables were selected based on their reported connections with sleep as outlined in the literature review in Chapter 2. The predictor variables were entered into the equation in three blocks: (1) health, (2) daytime functioning, and (3) total exposure. The ordering of the blocks was determined by the theoretical relevance of each predictor and was also consistent with Cohen and Cohen's recommendation that static predictor variables (health) should enter the models prior to dynamic predictors variables (daytime functioning, total exposure; Cohen & Cohen, 1983). The regression results are reported using unstandardized betas, standard error of the betas, standardized betas, their significance values, the R^2 for each block, and the ΔR^2 (See Tables 5-2).

All predictors combined accounted for a small amount of variance (19%) in TWT_s. Because the incremental contributions of each block were of particular interest, they are described in more detail below.

Health accounted for a significant increase in the variance for TWT_s (4%). Daytime functioning produced a significant increase in the amount of variance accounted for 'over and above' that accounted for by health for TWT_s (13%). Finally, the addition of ambient light to the models produced a significant increase in the amount of variance accounted for 'over and above' that accounted for by health, and daytime functioning for TWT_s (2%).

Table 5-1. Pearson Correlations between Subjective (Sleep Diary), Objective (Actigraphy) Sleep Variables, and Age, Health, Daytime Functioning Variables, and Ambient Light

Subscale	1	2	3	4	5	6	7	8	9	10
1. TWT_o	-									
2. TST_o	-.15	-								
3. TWT_s	.34**	.04	-							
4. TST_s	.18	.69**	-.46**	-						
5. Age	.02	-.16	.08	-.11	-					
6. Conditions[1]	-.01	-.09	.22*	-.22*	.29**	-				
7. FSS	-.05	-.03	.22*	-.21*	.27**	.32**	-			
8. STAI	.04	-.10	.24*	-.20*	.06	.17	.38**	-		
9. BDI-II	-.08	-.08	.34**	-.35**	.24*	.21*	.52**	.61**	-	
10. Total Exposure	-.06	.07	-.22*	.13	-.33**	-.17	-.23*	-.09	-.12	-

Note. TWT=Total Wake Time, TST=Total Sleep Time, FSS= Fatigue Severity Scale, STAI= State-Trait Anxiety Inventory, BDI-II=Beck Depression Inventory-Second Edition.

[1]Total number of medical conditions: Participants were asked to indicate whether they had experienced each of the following conditions: heart attack, other heart problems, cancer, AIDS, hypertension, neurological disorder, breathing disorder, urinary problems, diabetes, pain and gastrointestinal disorder. This variable reflects the total number of these conditions reported from this list.

*$p < .05$; ** $p < .01$.

Note: Subscript ‘s’ denotes subjective sleep and ‘o’ denotes objective sleep variables

Table 5-2. Summary of Hierarchical Regression Analysis for Variables Predicting Subjective Total Wake Time

Variable	B	SE B	β	R^2	ΔR^2
Step 1				.04*	.04*
Conditions[1]	5.58	2.80	.21		
Step 2				.17**	.13**
Conditions[1]	2.32	2.88	.09		
FSS	.74	3.25	.03		
STAI	-.20	.56	-.05		
BDI-II	2.95	1.13	.38**		
Step 3				.19**	.02
Conditions[1]	1.65	2.89	.06		
FSS	-.36	3.30	-.01		
STAI	-.14	.56	-.03		
BDI-II	2.94	1.12	.38**		
Total Exposure	-.00	.00	-.16		

Note. FSS= Fatigue Severity Scale, STAI= State-Trait Anxiety Inventory, BDI-II=Beck Depression Inventory-Second Edition.

[1]Total number of medical conditions: Participants were asked to indicate whether they had experienced each of the following conditions: heart attack, other heart problems, cancer, AIDS, hypertension, neurological disorder, breathing disorder, urinary problems, diabetes, pain and gastrointestinal disorder. This variable reflects the total number of these conditions reported from this list.

*p<.05, ** p < .01

CHAPTER 6
DISCUSSION

The main purpose of the current study was to examine the relationship between ambient light and sleep behavior in a sample of community-dwelling older adults. Previous research has shown that ambient light relates to various aspects of objective sleep, such as objective sleep onset latency, and objective wake time within sleep (Hood, et al., 2004; Shochat, et al., 2000; Wallace-Guy, et al., 2002). However, less research has been conducted examining the relationship between daytime ambient light exposure and *objective* and *subjective* sleep. The present study is innovative, because it is the first to: 1) examine ambient light's influence on *both* objective and subjective sleep collected currently; 2) implement a longer data collection period (12 days) compared to previous studies (2–7 days only), which provides a more representative view of older individuals' light exposure; 3) use a novel way to collect ambient light which includes duration and exposure; and 4) examine ambient light in the southeastern United States, a novel geographical location, which has unique conditions that influence light (i.e., milder winters allowing individuals to spend a greater amount of time outdoors and raising their light exposure.)

Review of Study Findings

Specific Aim 1: to Explore the Relationships between Age, Health, Daytime Functioning, Ambient Light, and Sleep (Objective and Subjective).

Heath conditions were positively associated with subjective total wake time and negatively associated with subjective total sleep time. These findings are consistent with the hypotheses and understandable given chronic health conditions have been shown to contribute to sleep disruption in later life (Bliwise, 2004; Drewes, 1999; Drewes, et al. 2000; Gislason, & Almqvist, 1987; Mallon, et al. 2002; Renko, et al. 2005; Schwartz, et al. 1999; Thorpy, 2004; Wilcox, et al. 2000). The failure to find associations with objective total wake time and total sleep time may be

due to the small number, only four participants, in the current study to report the medical conditions which previous contribute to objective sleep disruption in later life, such as osteoarthritis (Wilcox, et al., 2000), and neurological disorders such as Parkinson's disease (Thorpy, 2004) and Alzheimer's disease (Bliwise, 2004). Where as approximately twenty-three participants in the current study reported the medical conditions that have been shown to contribute to subjective sleep disruptions in later life such as coronary artery disease (Mallon, et al., 2002) and type 1 and type 2 diabetes mellitus (Renko, et al., 2005; Gislason, & Almqvist, 1987) included. Thus, the failure of health conditions to be associated with the objective sleep variables of total wake time and total sleep time may be due to the health types of conditions participants in the study.

Several interesting relationships between daytime functioning and sleep emerged. As hypothesized, poorer daytime functioning was associated with poorer sleep. Specifically, fatigue, anxiety, and depression, were positively related to subjective total wake time and negatively to subjective total sleep time. These findings are also consistent with previous research showing daytime functioning factors, such as fatigue, may contribute to sleep complaints (Whitney et al., 1997). In addition, depression has been linked to insomnia symptoms (Foley et al., 1999; McCrae et al., 2003), and sleep complaints have been linked to age-related risk factors including anxiety (Fichten et al., 1995). The objective sleep variables of total wake time and total sleep time however failed to be associated with measures of daytime functioning. This may be explained by previous research in poor sleepers that found poor daytime functioning is maintained by a subjective perception of an insufficient amount of sleep regardless of the actual sleep amount (Harvey, 2002).

Associations were found between ambient light and sleep. Among the sleep variables measured ambient light was significantly negatively related to subjective total wake time. This indicates that greater ambient light is related to better perceptions of nocturnal sleep. These findings were consistent with the hypothesis that greater ambient light would be associated with subjective total wake time. The discovery that ambient light is related to subjective and not objective sleep variables is interesting to note, particularly because past research has shown light to be related to objective sleep variables (objective sleep onset latency, and objective wake within sleep; Hood, et al., 2004; Shochat, et al., 2000; Wallace-Guy, et al., 2002). The differential findings of the current study may be due to the difference in measures used. The light measure employed in this study, Total Exposure, takes both duration and exposure of ambient light into account through a multiplicative relationship. Although this allows for a more thorough study of ambient light, it may average out time of day effects which may be more important to the objectively-measured biological relationship between sleep and light than to the relationship between light and subjective perception of sleep. Thus, the current study suggests that ambient light is associated with perception of sleep in a different way than with objective sleep. Given that the classification for insomnia uses subjective measurements of sleep quantity (McCrae et al., 2005), these results may indicate that increased ambient light affects sleep through more than just a biological pathway and suggests the possibility that ambient light interventions may decrease levels of insomnia and improve perceptions of sleep.

Specific Aim 2: to Examine the Amount of Variance in Sleep Accounted for by Ambient Light.

Ambient light accounted for roughly five percent of the variance in subjective total wake time. These results partially confirm the hypothesis that ambient light would account for a significant amount of the variance in objective and subjective sleep. Although ambient light

accounted for a seemingly small amount of variance in this variable, this could be the result of the light measure used, the population sampled, or the consistently high amount of light received in the study location (the southeastern US). Additionally, the small amount of variance in sleep accounted for in this normal population may translate to larger amounts in other subpopulations of older adults, particularly those who receive less light. For example, there are reasons to suspect that light therapy may improve sleep in breast-cancer patients (Liu, et al, 2005), nursing home residents, and individuals with insomnia (Moller, et al., 2004).

Specific aim 3: What Are the Incremental Contributions of Age, Health, Daytime Functioning, and Ambient Light (in that Order) to the Prediction of Sleep?

Hierarchical block regression results revealed that health, daytime functioning, and ambient light combined accounted for a small amount of variance (19%) in subjective total wake time. The incremental contributions of each block were of particular interest and are discussed below. Regarding the incremental changes, depression was significant for subjective total wake time.

There are many factors that may influence the current findings that show ambient light did not contribute to sleep over and beyond the other sleep-related variables examined. These findings may be the result of the conservative placement of ambient light in the final block of the analyses, given that aim 2 reports ambient light alone does predict sleep. There is a possibility that based on research findings regarding circadian rhythms (Dijk & Lockley, 2002), the time of day of ambient light, instead of overall light, may play a role on sleep. The current study also lacks the addition of activity (due to the naturalistic design of the study) which could be an important component to the ambient light-sleep relationship. The geographical location could also be contributing to the nonsignificant results. The participants in the current study received greater amount of light (1138 lux) than reported by other studies (554 lux; Jean-Louis, et al.,

2000). This could indicate that community-dwelling Florida residents are likely to receive the amount of light needed to influence sleep; thus, few, if any, received levels low enough to distinguish differences. If this is true, recommendations for increased ambient light may be more effective for those in other locations and settings. For example, research indicates nursing home residents typically only receive 19 minutes over 2,000 lux and 26% never reach this threshold (Shochat, et al. 2000). This stands in stark contrast to the present study of community-dwelling participants, in which all participants spent time over the critical 3,000 lux threshold for an average of 57 minutes. Thus, nursing home residences may benefit from increased ambient light. The current study also used a normative sample, and an analysis focusing strictly on individuals with insomnia may have yield different results for this subpopulation.

Limitations of the Study

Due to the correlational study design, causality cannot be assigned. The ecological validity that comes from a community dwelling sample may be lowered because a majority of the participants were white, female, college-educated, married, and living at home. Although controlled for, it is possible that sleep disorders other than insomnia may have been present in some of the participants. Although a self-report screening for primary sleep disorders was conducted, future research should used polysomnography to screen out other sleep disorders (i.e., sleep apnea, periodic limb movements disorder). The use of a convenience sample means that the sample might contain an excess of individuals who perceived their sleep to be either exceptionally good or exceptionally poor, restricting the diversity of the sample.

Implications and Future Directions

The potential theoretical and clinical implications for this study are as follows. Many components in the relationship between ambient light and sleep have been overlooked and require further examination (i.e., time of day of light and daytime activity). Considering that the

current findings show ambient light did impact sleep, although not over and beyond other variables that typically influence sleep, ambient light treatment interventions should still be considered for nursing home residents, older adults in more northern geographical locations, and individuals with insomnia. Future studies should be conducted to test the validity of these assumptions. In addition, a hierarchical block regression was preformed when a multivariate analysis may have been more appropriate to track daily ambient light and sleep changes. Such techniques were beyond the scope of the current paper, but should be considered in future research.

Conclusion

In community dwelling older adults, greater ambient light is significantly related to less subjective total wake time. Ambient light also accounts for a small amount of the variance in subjective total wake time. These findings demonstrate ambient light's contribution to sleep; however, not over and beyond other variables that typically influence sleep.

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BIOGRAPHICAL SKETCH

Ashley Stripling's interest in aging began during her undergraduate studies in Dr. Bluck's life story lab at the University of Florida. Since beginning graduate school she has worked in the Sleep Research Lab and been closely mentored by Dr. McCrae which allowed her to narrow her research interests and complete her master's thesis. The initial findings of her thesis were accepted into one of the competitive oral presentation slots at the Associated Professional Sleep Societies' 20th annual conference (SLEEP) and a poster presentation at 2006 Gerontological society of America (GSA) Conference. Ashley has also been accepted into the Aging Training program at UF and had the pleasure of fostering new interest in aging through co-mentoring a senior project. Psi Chi, the national psychology honor society, recently recognized her and the student for work on this project. Although Ashley's interests span research, mentoring, and clinical work, they all focus on aging. She hopes to continue to illuminate new areas in aging and spark interest in others.