# A Task's Cognitive Demands Influence Self-Reported Performance Variances Throughout The Day

by

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## Abstract

Chronotype describes the daily rhythm of an individual's performance capability as it changes through the day. It is defined using the Horne-Östberg Morningness-Eveningness Questionnaire (MEQ) which assesses time-of-day preference; or the Munich ChronoType Questionnaire (MCTQ) which indicates sleep timing parameters. My hypothesis was that chronotype predominantly reflects an individual's perceived daily rhythm in executive function. We tested this by comparing MEQ and MCTQ with the University of Toronto Inventory of Morningness and Eveningness (UTIME) Questionnaire which examines performance on scenarios requiring cognitive, physical, and/or emotional responses. Highest correlations were found between MEQ and UTIME tasks with high executive demand. The same UTIME tasks were also correlated with MCTQ (mid-sleep, free days), although the correlations were consistently lower than UTIME versus MEQ. Correlations among UTIME tasks and MCTQ (mid-sleep, workdays) were not linked to executive demand. Chronotype appears to reflect the perception of peak executive ability independently of sleep pattern.

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# List of Abbreviations

M ……………………………………………………………………………………………… (M)

E ……………………………………………………………………………………...…… (E)

N …………………………………………………………………………………..………… (N)

MEQ ………………………………………………… (Morningness Eveningness Questionnaire)

MCTQ ………………………………………………….. (Munich ChronoType Questionnaire)

MSW ………………………………………………………………... (Mid-sleep on Workdays)

MSF ……………………………………………………………… (Mid-sleep on Free Days)

MSF-Sc …………………………………...(Mid-sleep on Free Days – Sleep Duration Corrected)

MSF-Sac ………………………...(Mid-sleep on Free Days – Sleep Duration and Age Corrected)

ANT ……………………………………………………………….. (Attentional Network Test)

AD-ACL …………………………………………………… (Activation-Deactivation Checklist)

REM ………………………………………………………………... (Rapid Eye Movement)

SWS ………………………………………………………………….. (Slow Wave Sleep)

UTIME ………………………(University of Toronto Inventory of Morningness or Eveningness)

# 1 Introduction

Chronotype is a broadly defined term that describes a human being's performance capability as it changes throughout the day. Kerkhof and Van Dongen (1996), simply defined chronotype as preferred sleep-time. In other discussions, it has been interchangeably associated with morningness-eveningness (e.g. Neilsen, 2010). Phillips, Chen, and Robinson (2010) suggest chronotype is regulated by homeostatic sleep drive (which increases during wake and decreases during sleep) and circadian rhythms. Furthermore, there are additional clock-like mechanisms that can define rhythms of preference independently of the central circadian clock, and independently of sleep (Ralph et al., 2002).

Essentially all behavioural and physiological functions of living organisms exhibit circadian rhythmicity. These are systematic changes, expressed over the course of the 24-hour day, and which persist when the organism is held in constant environmental conditions (Chaudhury & Colwell, 2002). The outward expression of circadian rhythms is a reflection of an internal timing mechanism that is synchronized to the 24-hour day (Reppert & Weaver, 2001). In human beings, the most apparent expression of rythmicity is the daily cycle of sleep and wake (Hasher, Chung, May & Foong, 2002; Hasher, Goldstein & May, 2005). The timing of sleep and wake behaviour varies greatly among individuals (Roenneberg, Wirz-Justice & Merrow, 2003). Human beings are often characterized as larks (early birds), or owls to describe a fundamental difference among people who prefer morning (M), or evening (E), respectively, to perform daily tasks (DeYoung, Hasher, Dijikic, Criger & Peterson, 2007; Roenneberg, Wirz-Justice & Merrow, 2003).

Early research on human sleep-wake patterns demonstrated that the existence of M and E type individuals is correlated with "early" or "late" peaks in body temperature and performance efficiency curves throughout the day (Kleitman, 1963). For example, performance on some memory-related tasks tends to decrease across the day in M type individuals, and to increase across the day in E type individuals (Hasher, Zacks & Rahhal, 1999).

Whereas both M and E types of individuals are found in all populations reported, the distribution of type can vary. This is particularly evident during development, (for review, see

Schmidt, Collette, Cajochen & Peigneux, 2007). Studies in younger and pre-teen children have shown that M type tends to predominate among pre-adolescent children, but that a shift in predominance from M to E preference occurs at roughly 12 to 13 years of age (Hasher, Goldstein & May, 2005; Ishihara, Honma, & Miyake, 1990; Kim, Dueker, Hasher & Goldstein, 2002). A shift back toward M preference takes place from adolescence into adulthood, and occurs most cross-culturally visibly by age 50 in the majority of individuals tested (Schmidt, Collette, Cajochen & Peigneux, 2007).

In accordance with the literature demonstrating a shift from E type to M type, studies on cognitive performance have found variances in ability across the lifespan between individuals of different ages. For example, in a study of cognitive efficiency and circadian typology, Natale, Alzani, and Cicogna (2003) found that the fastest speed for completing complex tasks corresponded with the individual’s chronotype. Older M type individuals were quicker in the morning, while younger E type individuals demonstrated greater speed in the evening. The effect has also been found when simple cognitive tasks are completed.

A review of the literature indicates that many studies have suggested that one’s tendency for morningness or eveningness influences performance on a wide range of cognitive and physical functions (Schmidt, Collette, Cajochen & Peigneux, 2007). Cognitive functioning is an all encompassing term referring to those mental processes that control an individual’s ability to perform a range of activities including, but not limited to, attentional capacity, executive and inhibitory functioning, storage and memory retention and retrieval (Coltheart, 2001; Schmidt, Collette, Cajochen & Peigneux, 2007).

Currently, the most widely used self-report scale to measure circadian typology is the Horne-Östberg Morningness-Eveningness Questionnaire (MEQ), developed in 1976 (Caci, Deschaux, Adan & Natale, 2009; Horne & Östberg, 1976). The MEQ consists of 19 items pertaining to one’s average sleep-wake times, and subjective variances in alertness in the M versus E. The questions refer to an individual’s preferred time for mental and physical performances, and based on one’s response, subjects are classified into one of five categories: definitely M type, moderately M type, neither (N) type, moderately E type, or definitely E type. Outcome scores range from 16 (extreme E type) to 86 (extreme M type), with scores from 42 –

58 indicating an individual who classifies as N type. While initial testing with the MEQ found an approximately 100 minute delay between the bedtimes of M types and E types, it did not find significant differences in sleep length (Horne & Östberg, 1976).

While the MEQ accurately assess tendency for morningness or eveningness, the definition of morningness and eveningness is not clear. More specifically, the MEQ does not outline which types of activities are predominately being used to derive a classification of one's tendency for morningness or eveningness. I hypothesize that the MEQ's definition of M or E tendency is predominately based on a self-report of one's performance on tasks with high executive control demands. For example, reading and consolidating studied material, or organizing thoughts to form a logical argument for one's position on a particular subject matter. While executive functioning may require a relatively elevated level of alertness, a somewhat lesser degree of alertness may be required when performing tasks that use lower-level cognitive processes, such as reading a book by one's favourite author just for pleasure and relaxation purposes. Not all tasks conducted by individuals throughout the day require executive functioning; however, these tasks still require some degree of cognitive ability or functioning in order to be properly completed. Research on diurnal variations in cognitive performance has suggested certain cognitive abilities may be more correlated with circadian typology than other abilities, and this difference may be observed depending on the specific task at hand (Barbosa & Albuquerque, 2008; Yang, Hasher, & Wilson, 2007; Ramírez et al., 2006).

Secondly, the MEQ only describes the subject's optimal self-reported performance based on circadian typology (a theoretical point in the day), instead of profiling performance variations *across* the day. Further to profiling morningness or eveningness preference at only one time-of-day, the MEQ also does not profile performance variations across the lifespan, which would be important to track changes in ability as they occur across the lifespan.

A second scale used to quantitatively assess an individual's timing of sleep within the 24-hour day is the Munich ChronoType Questionnaire (MCTQ) (Roenneberg, Wirz-Justice & Merrow, 2003). Consisting of a total of 44 questions, the MCTQ asks actual sleep times for work and free (e.g. weekend) days, and uses the midpoint between sleep onset and wake up as the phase reference point for sleep to provide four measures of chronotype: mid-sleep on work days (MSW), mid-sleep on free days (MSF), mid-sleep on free days sleep duration corrected (MSF-Sc), and mid-sleep on free days sleep duration and age corrected (MSF-Sac). The MCTQ's aim of providing a quantitative assessment of sleep was meant to be in response to other sleep logs and measures of morningness-eveningness such as the MEQ, which are most commonly criticized for providing only a qualitative assessment based on one's own subjective rating of chronotype (Roenneberg, Wirz-Justice & Merrow, 2003). The MCTQ also collects information regarding the clock time of becoming fully awake, whether an individual takes a nap, reads before bed, the amount of daily exposure to light, and the morningness or eveningness of family members; however these pieces of information are not used to derive the four mid-sleep scores (Zavada, Gordijn, Beersma, Daan & Roenneberg, 2005).

While the MCTQ is beneficial in providing a quantitative assessment of one's mid-sleep profile, I believe that the MCTQ, like the MEQ, also has shortcomings. For example, while the MCTQ tests an individual's sleep profile, I believe it is an insufficient tool for providing a complete explanation of chronotype and how it will influence one's performance variances throughout the day.

Zavada, Gordijn, Beersma, Daan and Roenneberg (2005) conducted a study to examine the relatedness of the MEQ with the MCTQ's four outcome scores. The results indicated that across an approximately normal distribution of MEQ scores, MSF was more correlated ($r$ = -0.73) with MEQ than was MSW ($r$ = -0.61). The authors also concluded that the estimated actual timing of sleep on free days yielded by the MCTQ was the most strongly of the four scores to correlate with MEQ, and that in particular, the timing of mid-sleep on free days was a good predictor of chronotype (as determined based on sleep preferences). The strong correlation between MSF and MEQ suggests that it is the best of the MCTQ scores to provide an indication of one's tendency for morningness or eveningness. The study did not provide an explanation as to why the correlation values between MEQ and MCTQ were negative values; this will be considered later on in our study.

In order to achieve a more comprehensive understanding of one's performance variances throughout the day, it is necessary to examine how one's innate circadian rhythms influence the person's performance in various scenarios, including cognitively, physically, and emotionally based tasks.

## 1.1 Cognitive and Attentional Demands and Circadian Rhythms

As mentioned above, different activities show cognitive performance variances across the day that may or may not be correlated with an individual's tendency for a certain circadian typology. Furthermore, certain activities may be performed at some consistent level of ability throughout the day. As reviewed in West, Murphy, Armilio, Craik, and Stuss (2002), the influence of time-of-day on cognitive functions can interact with developmental and individual differences. Studies have found that tasks involving long-term memory retrieval do not produce performance variances across the day, and therefore are not likely to be correlated with an individual's tendency for morningness or eveningness. Conversely, tests of working memory demonstrate a positive correlation with subjects' circadian typologies suggesting that as the day progresses into evening, an E type individual will more likely demonstrate better working memory, with the reverse being observed in a M type individual (Barbosa & Albuquerque, 2008; Ramírez, et al., 2006). These differences in performance in scenarios involving either long-term memory or working memory indicate that not all cognitive tasks are equally associated with one's classification of being a M or E type individual, but rather that task-dependent differences do exist in relation to their association with morningness or eveningness.

Memory retrieval can take place by at least two routes: a deliberate or an unintentional route. In deliberate (explicit, controlled) recall, an individual attempts to effortfully retrieve or recall some fact or event, while in unintentional (implicit, uncontrolled) recall, one's behaviour or ability to bring to mind some fact or event is triggered by the past without conscious knowledge or awareness, or even totally unconsciously (May, Hasher & Foong, 2005). Participants in a study contrasting implicit versus explicit recall at peak and off-peak times of day in younger E type individuals and older M type individuals, were tested at either their optimal or suboptimal times of day on implicit and explicit stem completion tasks, or on implicit category generation. When completing implicit recall, participants were not given any time constraint under which to complete the task. Time-of-day patterns were exactly reversed for the implicit and explicit measures in both younger and older participants – for implicit memory, participants performed better at their off peak time-of-day, while explicit performance was found to be best at their peak time-of-day (May, Hasher & Foong, 2005).

In a more recent study by Yang, Hasher, and Wilson (2007) a speeded retrieval task was used to investigate time-of-day effects in association with automatic and controlled memory retrieval. M type adult participants were tested at either their peak or off-peak times on a speeded implicit or explicit stem completion task. Results indicated that performance on controlled retrieval tasks showed greater priming at peak as opposed to off-peak times of day. Conversely, on automatic retrieval tasks, there was no performance difference between peak and off-peak times of testing. The results of Yang et al. for automatic retrieval differ from those of May, Hasher, and Foong (2005). Yang et al. explained the variation noting that performance on their automatic retrieval tasks showed no variance for time of testing because unlike the previous experiment, their study used a speeded retrieval task. Their explanation is supported by research by Rossnagel (2001) who suggested that giving participants unlimited time may interfere with their performance on implicit tasks.

Fluid and crystallized intelligence may also show fluctuations with time-of-day in conjunction with one's chronotype. Crystallized intelligence includes that information learned and stored throughout one's life, ranging from basic knowledge, to one's learned vocabulary. Fluid intelligence differs in that it requires the use rather than acquisition of knowledge. Hasher, Goldstein, and May (2005) demonstrated that semantic knowledge, and other types of crystallized intelligence, remain consistent across the day. These results were replicated by Goldstein, Hahn, Hasher, Wiprzycka, and Zelazo (2007), who also demonstrated that when measured, crystallized intelligence did not show variances between one's peak and off-peak testing times. However, these authors did demonstrate a synchrony effect for measures of fluid intelligence at one's optimal versus non-optimal time-of-day based on the individual's chronotype. The adolescents in the study tested at their optimal times of day showed significantly better performance on measures of fluid intelligence compared to those adolescent participants tested at their non-optimal times of day.

Attention is known to vary with time-of-day between M and E type individuals. Matchock and Mordkoff (2009) suggested that to better understand circadian rhythms, it was necessary to review attention and its three components – alerting, orienting, and executive control. In an evaluation of the literature on attention, Matchock and Mordkoff (2009) defined its three components. The alerting network is meant to increase and sustain arousal and vigilance to better prepare the organism to detect any upcoming stimuli; it is believed to be task specific (phasic alertness). The alerting network is believed to be distinct to some degree from intrinsic alertness, which is thought to be non-specific (tonic alertness). The orienting network works to select specific information from an incoming array of information, in order to determine which information is and is not needed. Thirdly, the executive control component of attention is involved in planning and decision-making, detection of errors, resolution of conflict, and inhibitory control processes (Matchock & Mordkoff, 2009).

In their study, Matchock and Mordkoff (2009) examined diurnal changes in how efficient the three components of attention were in two groups of individuals with different chronotypes, by employing the Attentional Network Test (ANT) developed by Fan, McCandliss, Sommer, Raz, and Posner (2002) to serve as a measure of attention, at four time points in the day. Subjects also completed the MEQ as a measure of chronotype, and the Thayer activation-deactivation checklist (AD-ACL) as a measure of self-reported tonic alertness. The results indicated that the alerting, orienting, and executive control components of attention function independently of one another. More importantly, the three components showed different interactions with time-of-day. Alerting interacted with time-of-day, demonstrating an increase in the second half of the day only among either M or N type individuals. Conversely, orienting was not found to interact with time-of-day or chronotype. Executive control was found to be lower in the middle of the day for M, N, and E type chronotypes.

Matchock and Mordkoff (2009) suggested that the most interesting of the findings was the modulation by chronotype of the time-of-day changes in the alerting component of attention. Specifically, that opposed to the expected decrease in efficiency, M and N type individuals demonstrated increasing alertness from morning to evening, while E type participants did not show increases in their alerting scores. Fan and Posner (2004) as cited in Matchock and Mordkoff (2009) explained that "larger alerting numbers generally arise when one group has difficulty in maintaining alertness without a cue" (p. S211). Meaning, given that M and N type individuals often express decreased self-reported alertness, such individuals can produce such large alerting scores on the ANT in the second half of the day because they can best make use of cues that raise their alertness, even only temporarily. Conversely, E type individuals do not experience diminished alertness as the day progresses, therefore their ANT alerting scores do not demonstrate an increase the cues as much at this time-of-day as do their M and N type counterparts.

Thus, cognition, memory, and attentional demands can each be broken down to show how they are differentially related to and influenced by circadian rhythms. Long-term memory does not interact with one's preference for morningness or eveningness, while working or short-term memory is highly influenced by the time-of-day at which an individual is tested. Providing time constraints to an individual trying to complete different cognitive tasks can also alleviate time-of-day differences in ability to recall information. Finally, attention can be subdivided into different components, each of which is again differentially associated either positively, negatively, or not at all with one's peak or off-peak performance time-of-day. Therefore, we see that various cognitively based activities do indeed show a variance in how they are affected by the performing individual's chronotype.

## 1.2 Physical Demands and Circadian Rhythms

Physical activity performance is also affected by daily bodily fluctuations associated with circadian rhythm and sleep-wake pressures (Reilly, 1990). Atkinson and Reilly (1996) noted that several components of sports performance, including flexibility, muscle strength, and short term high power output, show a variance with time-of-day. Various forms of physical activity may show variances in their cognitive load, ranging for example from physical tasks that require a high amounts of strategy for successful completion, to those where one need not consider so much the strategy behind successful completion, but rather the self-motivation to carry out the exercise are necessary.

Brown, Neft, and LaJambe (2008) studied a collegiate rowing crew to understand how their circadian preference for morningness versus eveningness influenced their performance ability on a rowing task compared to a standing broad jump. Rowing was considered to be a highly trained, deliberately conditioned muscular performance task, while the standing broad jump was deemed a natural, but unconditioned muscular performance. M type individuals had significantly slower rowing speeds in the evening compared to morning sessions. Conversely, among E and N type individuals, no significant change in speed was found between morning and evening performance on the rowing tasks, yet the authors noted that some E type rowers showed performance increases in rowing speed from morning to evening. However, unlike the rowing task which did show a degree of performance difference between M and E type individuals, when comparing M and E type individuals on the unconditioned standing broad jump task, the authors found no significant difference in performance across the day between the two groups. These results suggested that the rowing task, which was conditioned and required not only physical strength and exertion, but also cognitive planning was influenced by the individual's propensity for morningness versus eveningness, however, in comparison, broad jump performance did not demonstrate a particular time-of-day superiority, nor was it affected by chronotype. Given the observed difference in performance across the day was found to be significant only in M type individuals, but not in E or N type individuals for the rowing task, it may be possible that the results were brought about by an interaction between the participants' endogenous bodily rhythms together with temporal adaptation in performance brought about by habitually training at a particular time-of-day.

Many human performance measures, such as muscle strength, anaerobic power output, and one's work or self-exertion rate, have been noted to broadly follow the circadian body temperature curve (Reilly & Edwards, 2007). In a study examining cycling activity, Atkinson, Todd, Reilly, and Waterhouse (2005) found that cycling performance was worse in the morning compared to the afternoon, regardless of whether the participant classified as a M or E type individual. An earlier study by Arnett (2002) yielded similar results to those of the cycling study, however this time, male and female competitive swimmers were used as participants. Among swimmers, afternoon performance was superior to morning performance, leading the author to suggest that the circadian body temperature curve likely influenced physical performance ability across the day. However, Arnett (2002) did not measure each participant's tendency for morningness or eveningness prior to conducting the study, but did however note that the 6 participants did demonstrate better evening compared to morning performance prior to training. Based on this, it seems important to suggest the possibility that swimmer's better afternoon performance was not only mediated by the circadian body temperature curve, but by the participants' potential predisposition to eveningness preference. Further testing would need to be conducted to verify this hypothesis.

It is possible that the discrepancy between the two above mentioned cases of physical performance and time-of-day variations (rowing, which shows a morningness-eveningness variation, versus swimming and cycling, which show a later day peak in performance regardless of the participants' preference for morningness or eveningness) is that physical tasks with a greater cognitive load (in this case, rowing) might not only be tied to fluctuations in one's physical stamina throughout the day, but also to shifts in cognitive performance ability across the 24-hour day. Conversely, those physical tasks with a lesser cognitive load (in this case, cycling or swimming) may be predominately dependent on one's physical stamina, which may be less so related to tendency for morningness or eveningness than are more cognitively demanding activities. However, such conclusions cannot be definitively drawn without further experimentation.

Travelling on flights across time zones results in desynchronization of one's circadian rhythms. The resulting feelings of disorientation, light-headedness, impatience, lack of energy and general discomfort that one may experience are referred to as symptoms of jet lag (Reilly & Edwards, 2007). The greater the number of time zones an individual travels across increases the severity of jet lag symptoms. Other factors that influence an athlete's degree of impairment include the flight's direction eastward or westward, timing of meals, tendency for morningness or eveningness, and one's motivation to adapt (Winget, DeRoshia, & Holley, 1985). Furthermore, while interindividual differences exist producing a range of symptom severity, many people who travel across time zones fail to recognize how they are affected, in particular in tasks requiring concentration and complex coordination (Reilly & Edwards, 2007). Meijer, Deboer, and Michel (2008) reviewed the literature and found that studies do demonstrate that jet lag can cause athletic performance to decline, as a result of one's desynchronized physiological state and sleep disturbances. Recht, Lew, and Schwartz (1995) studied the performance of major league baseball teams across three seasons. They found that independent of 'home-field advantage', after travelling eastward, visiting baseball teams performed less well than the home team against which they were competing. However, this difference was not found following westward travel by baseball teams. This suggests that time changes associated with eastward travel may be more difficult to recover from than those changes needed for westward travel. Hill, Hill, Fields, and Smith (1993), evaluated the effects of jet lag on factors linked with athletes' sports performance. The authors noted that after travel across time zones, athletes demonstrated disrupted mood state and reduced dynamic state, power and work capacity were diminished for two days, indicating that even among highly trained athletes, jet lag can negatively influence performance ability. The authors found that the effects of jet lag were nearly eliminated after three or four days of adaptation time. However, many athletes must travel across time zones to play only one or two games and in many instances will likely not have three or four days of time in which to resynchronize their circadian rhythms prior to performing their physical activity. To attempt to lessen symptoms of jet lag, Reilly and Edwards (2007) suggest that taking into account time of flight departures and arrivals, and altering training times to account for direction of travel may help to decrease the negative effects of travelling across multiple meridians.

As was demonstrated with cognitive activities, the above literature review indicates that various forms of physical activity are also differentially affected by time-of-day at which they are completed. Therefore, in determining when an individual can best perform a physical task, it is necessary to consider the components of the activity in order to determine whether there are in fact optimal times of day dependent upon an individual's chronotype at which he or she may best complete the task, or if instead the activity is not specific to time-of-day, but more to one's physical stamina or motivation.

## 1.3 Emotional Demands and Circadian Rhythms

Finally, mood and emotionality, like cognitive and physical functioning, also seem to be tied to one's chronotype. More specifically, adequate sleep duration may serve as both a biobehavioural regulatory and restorative process that regulates one's daily emotional experiences and allostatic loads of emotional stress (Vandekerckhove & Cluydts, 2010). Conversely, sleep deprivation or restriction can negatively affect one's control of mood, oftentimes contributing to the report of feelings of sadness (Dahl, 1999). However, before considering the effects of sleep duration on emotion, I will discuss the relationship between tendency for morningness versus eveningness and mood and emotional state.

Hasler, Allen, Sbarra, Bootzin, and Bernert (2009) noted that more than three decades of research have demonstrated the existence of circadian rhythm abnormalities in emotional regulation and mood disorders. Depression research has shown links between the disease and E typology (Hasler, Allen, Sbarra, Bootzin, & Bernert, 2005). Mansour et al. (2005) also noted that among bipolar I individuals, even after accounting for age, persons with the disorder showed a significantly higher preference for eveningness as compared to controls. Based on this information, it appears that among individuals with both bipolor and unipolar depression, there is an increased tendency for eveningness compared to healthy controls.

Hidalgo et al. (2009) assessed the association between chronotype and level of depression among healthy individuals. They sought to understand whether the relationship between preference for eveningness and incidence for depression among individuals with psychiatric disorders was also present among individuals presently deemed healthy. Individuals with a past or present psychiatric history, and or history of drug use and or diagnosed disease were excluded from participation in the study. Qualifying participants were then assessed for depressive symptomatology, tendency for morningness or eveningness, and completed a hopelessness questionnaire. The results indicated that even among healthy participants, eveningness preference was associated with a heightened risk of moderate-to-intense depressive symptoms, despite the use of the ‘report of psychiatric disorders’ as an exclusion criterion. The authors concluded that the results of their study were to a certain extent, an affirmation of past studies that suggested eveningness is not merely a characteristic of depression, but rather may indicate a pre-morbid trait for the disease. Hidalgo et al. also noted that there was no difference between the self-reported sleep-durations of M or E type individuals, indicating that sleep length was not the likely cause of depressive symptomatology. This study indicates that even among individuals who present as being healthy, the tendency for eveningness may be associated with greater likelihood for the onset of a mood or emotional disorder, thus affirming the link between one’s circadian rhythm and the potential for unstable emotions or mood. In work by Pabst, Negriff, Dorn, Susman, and Huang (2009), the authors also noted that even in a study comparing normal-weight versus overweight females, depressive symptoms were more common among E type women. This lends support to the conclusions of Hidalgo et al., suggesting that not only among seemingly mentally healthy but also among physically healthy individuals, depressive symptomatology is associated with a tendency for eveningness.

Willis, O'Conner, and Smith (2004) conducted a study on morningness versus eveningness preference and its influence on anxiety. Unlike depression, they found that participants' anxiety ratings were higher in the morning. Participants were tested both in the morning and afternoon (ie. at their optimal and suboptimal time, depending on their chronotype), however, no interaction was found between time of testing and morningness-eveningness preference. The results of Willis et al.'s study confirm that some mood or emotional disorders (such as anxiety) do not occur more often with one particular chronotype as is seen with disorders such as depression, but rather can be more prevalent specifically at one time-of-day, regardless of one's tendency for a particular time-of-day. Interestingly, in an earlier study, Gau, Soong, and Merikangas (2003) found that among their sample of Taiwanese teenagers, E type participants were more likely than M type participants to report anxiety symptoms. They reported that to their knowledge, they were the first study to demonstrate the association between tendency for eveningness and symptoms of a tendency to experience increased anxiety. However, no mention is made of whether these symptoms were reported more commonly at one time-of-day or another, or if E type participants simply were more likely to report suffering from anxiety in comparison to M type participants. Gau et al. also indicated that of their participants who were more likely to express symptoms of mood and anxiety disorder together with a tendency towards eveningness, male participants were more likely than females to match this profile.

Nightmares are associated with negative affect, in that they scare or distress the individual experiencing them. Nielsen (2010) examined whether the likelihood of experiencing frequent and distressing nightmares was associated with tendency towards morningness versus eveningness, and gender. In Nielsen (2010)'s literature, it was noted that the most vivid dreaming an individual experiences is during rapid eye movement (REM) sleep and occurs near the early morning peak of REM propensity, which is also the time of one's sleep when most nightmares occur. Furthermore, the author noted the increased likelihood for E types to awaken from and subsequently recall their most intense dreams and nightmares more frequently than M types, given that REM sleep propensity is time locked with the minimum core body temperature, and more E type as opposed to M type individuals are likely to be awake due to social schedules prior to their body being ready to be fully awake.

Nielsen (2010) noted that there was a significantly strong association between recalling more frequent and distressing nightmares, and a tendency towards eveningness for female subjects, with definite E types presenting with the most severe nightmares. This relation did not hold for male participants. The author suggested that the findings were consistent with the possibility that nightmares are the expression of a more pathological factor that is both characteristic of eveningness, and is associated with the onset of affective symptoms such as neuroticism and depression. These results again support the idea that emotionally linked factors such as depression and neuroticism can interact with chronotype to increase the propensity for experiencing vivid and distressful nightmares.

Morningness-eveningness has also been examined in relation to positive affect. Clark, Watson, and Leeka (1989) studied the two basic dimensions of positive and negative mood of 196 colleges at 7 times in the day over the course of a week. Their results indicated a significant time-of-day effect for positive affect, but not for negative affect, which instead demonstrated no overall diurnal trend. The authors found that among 78% of participants, mean positive affect rose quickly from 9 a.m. to noon, remaining relatively constant until 9 p.m., after which it showed a dramatic decrease among 85% of participants. In relation to chronotype, M type individuals showed the highest overall level of positive affect, followed by those who classified as N type and E type.

Recent work on circadian variations of consumers' emotional state demonstrated that M type shoppers were in a more positive emotional state in the morning than in the evening, however the predicted reversed pattern did not reach a level of significance among E type participants (Chebat, Dubé, & Marquis, 1997). The authors suggest the results can be interpreted to mean that societal schedules where activities are scheduled for M type people may benefit such individuals, however those with a tendency for eveningness may be less adapted or suited for such a daily structure.

Given the influence of sleep on emotional regulation, is possible that one's preference for M or E may not necessarily be the only indicator of an individual's mood across the day and throughout the entire week, but rather that one's varied sleep schedule on work versus free days may potentially also influence mood and emotion. For example, REM sleep deprivation significantly impacts the way daily experiences are processed, consolidated, and buffered. This sleep loss significantly amplifies negative emotional reactivity, while subsequently decreasing the positive effects of positive events (Zohar, Tzischinsky, Epstein, & Lavie, 2005). In accordance with the already discussed importance of sleep and the negative consequences of REM sleep deprivation, Vandekerckhove and Cluydts (2010) reviewed the literature and found that research has indicated that sleep deprivation is oftentimes followed by nights of both increased REM sleep and slow wave sleep (SWS). This sleep rebound suggests that a certain amount of REM and SWS are necessary. Given that sleep is known to have an emotionally restorative role, these findings nearly consistently suggest that while REM sleep deprivation results in reduced emotional regulation, increased REM sleep serves an adaptive function in positively enhancing mood and emotion stability (Vandekerckhove & Cluydts, 2010). This line of thought is in agreement with Zohar, Tzischinsky and Epstein (2003), who suggested a cognitive-energetic model of affective reaction whereby in a state of sleep deprivation, following goal-disruptive events, negative emotions were amplified, while following goal-enhancing events, positive emotions decrease as a result of inability to capitalize on new opportunities.

At the neurological level, sleep deprivation also increases hypersensitivity of the amygdala, known to be a brain centre for emotional regulation, especially to negative emotional stimuli (MacKay, 2003; Yoo, Gujar, Hu, Jolesz, & Walker, 2007). Sleep loss also impairs affective neural systems, consequently disrupting identification of affective social cues. This results in impaired accuracy of judgments of human facial emotions, especially those threat and reward relevant categories (van der Helm, Gujar, & Walker, 2010). These results further emphasize that unlike cognitive and physically demanding tasks, emotionally based tasks may be less regulated by one's preference for morning or evening, and more by an individual's sleep duration. This is not to say that morningness-eveningness tendency play no role in emotion regulation, but rather that performance in emotionally loaded situations are influenced significantly by sleep, and less so by personal preference.

Thus, just as cognitive and physical task scenarios show differential relation to chronotype when considering performance, emotional tasks are also variably associated with one's circadian typology and homeostatic sleep-wake pressures.

## 1.4 Intent of the Current Project

In light of recent research indicating that cognitive, physical, and emotional tasks show performance variances across the day, depending on the specifics of the activity, I propose that it is necessary to examine self-reported performance variability on these various tasks in order to understand how one's tendency for morningness or eveningness, and homeostatic sleep wake influence ability to complete different tasks throughout the day. To test these performance variances between different tasks, I created the University of Toronto Inventory of Morningness or Eveningness (UTIME) (Appendix 1).

The UTIME consists of 20 questions ranging in their cognitive, physical, and emotional load. It is meant to assess one's self-perception of one's abilities on tasks requiring varied amounts of processing, executive and inhibitory control, physical endurance and performance, and emotional regulation or emotionality. The questions are based on the aforementioned research regarding cognitive, physical, and emotional variability or stability depending on the task and its performance at different time points throughout the day. Participants' UTIME scores are compared with their MEQ and MCTQ scores, in order to understand how self-reported tendency for morningness or eveningness, along with self-reported sleep wake patterns, are associated with one's own documented performance on various task scenarios that can be encountered throughout the day. I believe that MEQ score will be most strongly associated with those highly cognitive tasks, while MCTQ scores will be associated with those tasks whose performance is dependent upon homeostatic sleep wake drive. Finally, I believe that even though participants will be asked to provide their performance variations related to memories of their workday schedules, respondents will provide their performance for free days.

# 2 Methods

## 2.1 Creating the UTIME

Students and faculty in the Department of Psychology at the University of Toronto were asked to submit questions regarding tasks or situations that might be encountered over the course of the day. Twenty questions were selected by my supervisor (Dr. Martin Ralph) and myself from the pool to reflect tasks with a range of cognitive, physical, and emotional demands.

Care was taken to reduce the biases or concerns that subjects may have had based on the wording of the questions. For example, Mayer and Tormala (2010) found that men and women respond differently to questions depending on how they are framed. Men tend to be more persuaded by “I think” framing, while women are more persuaded by “I feel” framing. In order to keep the questions gender neutral, questions were not framed in terms of “I think” or “I feel” to ensure participants of either gender were able to respond in the most unbiased manner. The 20 UTIME questions are attached (Appendix 1a).

When these questions were presented, the subjects were asked to respond with how they *think they would perform* if presented with the situation in real life, not how they think they *should* or might *want* to perform. All questions were organized and reformatted into the following presentation:

> Step 1: Indication of wake-up and going to sleep times. A grid was provided so participants could indicate the beginning and end of their wake time on the days in question.
>
> Step 2: Plot of responses (worst to best) for each of the 20 questions. The x-axis denoted time-of-day, from 3:00 a.m. across 24-hours to 3:00 a.m. The y-axis denoted performance, from 0 to 1, in increments of 0.1. (Activity indicated during sleeping hours was ignored during the analysis). Participants could use as many points as needed to indicate changing performance response levels throughout the day, or could draw a continuous curve.
>
> Step 3: Question regarding performance on a cognitive/physical/emotional task

Two examples demonstrating how to mark wake and sleep times, and performance points were provided for participants prior to asking for their response on the 20 questions (Appendix 1b and 1c).

The questions used in the UTIME were not oriented to any particular age or population. Instead, the questions are flexible and new questions can be posed in order to understand performance variances for different tasks.

## 2.2 Participants

One hundred seventy-four participants from the University of Toronto, between the ages of 17 and 46 were recruited from Introductory Psychology at the University (for partial course credit) or volunteered to partake in the study. Twenty participants provided data that were not interpretable, leaving a total of 154 subjects (49 males and 105 females). Participants were asked to read and sign a consent form that outlined information about the study, and were asked to fill out a background information profile. The University of Toronto Ethics Committee approved the study protocol.

## 2.3 Materials

Participants received a package containing the MCTQ, MEQ, and UTIME questionnaires.

## 2.4 Procedure

### 2.4.1 Completion

Participants completed the MCTQ, MEQ, and UTIME questionnaires in one sitting. Participants were not given a time constraint in which to finish the questionnaires in order to allow participants sufficient time to consider each scenario and imagine themselves in such a case. On average, subjects generally required 50 minutes to complete the questionnaires and background information. No new instructions were given to participants regarding the completion of the surveys other than those already specific to the three questionnaires.

### 2.4.2 MCTQ Scoring

The MCTQ was scored using a Microsoft Excel template that calculates mid-sleep on workdays and free days, based on calculations made from subject data (age, bedtime, time to fall asleep and wake up time on work days and free days). This template also allows for corrections to mid-sleep on free days to be made based on sleep duration, and on sleep duration plus age, however, due to the small sample size and limited age range, these corrections were not applicable.

### 2.4.3 MEQ Scoring

The MEQ was scored according to the published procedures (Horne & Östberg, 1976). Data were normalized with the following formula:

$$\frac{(\text{Raw MEQ Score}) - (\text{MEQ}[min])}{(\text{MEQ}[max]) - (\text{MEQ}[min])} = \text{Normalized MEQ score}$$

### 2.4.4 UTIME Scoring

The UTIME was scored by connecting a subject's self-reported performance variance time-points on the graph, and recording performance points for each hour. This recorded information was then used to calculate the area under the graph, and a simple linear transformation was applied to the data points. This value is the relative strength of preference for morning versus evening and is independent of overall self-assessment in performance. UTIME data were normalized with the following formula:

$$\frac{(\text{Raw UTIME Score}) - (\text{UTIME}[min])}{(\text{UTIME}[max]) - (\text{UTIME}[min])} = \text{Normalized UTIME score}$$

### 2.4.5 Independent Rating of UTIME Questions

Faculty members in the Department of Psychology at the University of Toronto were polled for their assessment on the degree to which each of the 20 UTIME tasks were more or less cognitively, physically, or emotionally demanding, and to what degree executive control was involved in each response. In more common terms, the rating of executive control was considered as how much decision-making or explicit recall of items was necessary to respond.

### 2.4.6 Statistics

Descriptive statistics were computed for the MEQ, MCTQ, and UTIME scores. Correlations used the Pearson *r* correlation statistic to compare UTIME versus MEQ scores, UTIME versus MCTQ scores, and MEQ versus MCTQ scores. A Wilcoxon signed rank test was used to compare the ranking of correlations between UTIME responses and MEQ or MCTQ mid-sleep. Data were analyzed using SPSS 17.0 for Windows (SPSS, Inc., Chicago, Ill). Significance level was set at $p \leq 0.05$.

# 3 Results

## 3.1 Descriptive Statistics

### 3.1.1 Participant Data

The average age of participants was 20.43 years of age. The most frequent age was 18 years (Figure 1). The ratio of males to females is 7:15, for 154 total participants.

### 3.1.2 MEQ Scores, MCTQ Results, and UTIME Results (Table 1)

The MEQ has a range of 16 to 86 (E to M type, respectively) so when normalized, the scores range between 0 and 1, with values approaching 1 indicating a tendency towards morningness. The mean normalized MEQ score, 0.405 (raw MEQ score: 44.350) for our data, indicates that on average, most participants fell just outside the range of being moderately E types, and would be classified as N type according to general convention.

On the MCTQ, increasing values for normalized scores indicates a tendency for a later mid-sleep time, suggesting a more E chronotype. Mid-sleep values on free days had a higher value, (later sleep) than workdays. This indicates that on free days, when there are less outside restraints on one's schedule, on average, participants indicated that they were more likely to have a later mid-sleep value.

All of the normalized UTIME averages are below 0.500, demonstrating that on average, participants indicated that their performance was higher in the second half of the day.

Figure 1. Frequency distribution of participants' ages

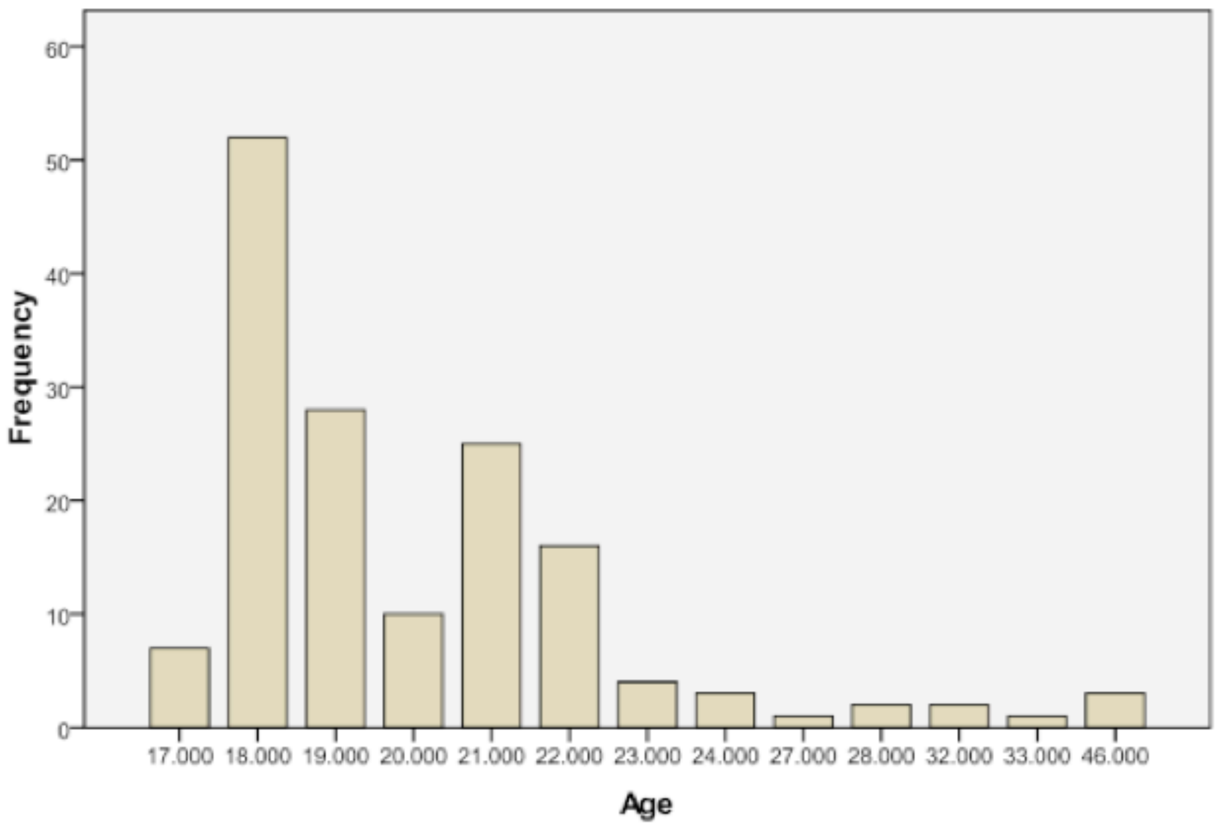

Frequency
0
10
20
30
40
50
60
17.000
18.000
19.000
20.000
21.000
22.000
23.000
24.000
27.000
28.000
32.000
33.000
46.000
Age

Table 1. Means and standard deviations for all MEQ, MCTQ, and UTIME results

| Questionnaire | Mean | Standard Deviation |
|---|---|---|
| MEQ (normalized score) | 0.405 | 0.133 |
| MSW (time-of-day) | 4.269 (a.m.) | 1.018 |
| MSF | 5.911 | 1.299 |
| UTIME #1 (normalized scores) | 0.472 | 0.123 |
| UTIME #2 | 0.487 | 0.126 |
| UTIME #3 | 0.359 | 0.118 |
| UTIME #4 | 0.437 | 0.128 |
| UTIME #5 | 0.457 | 0.133 |
| UTIME #6 | 0.461 | 0.123 |
| UTIME #7 | 0.447 | 0.102 |
| UTIME #8 | 0.394 | 0.125 |
| UTIME #9 | 0.454 | 0.113 |
| UTIME #10 | 0.441 | 0.122 |
| UTIME #11 | 0.432 | 0.130 |

| | | |
|---|---|---|
| UTIME #12 | 0.433 | 0.116 |
| UTIME #13 | 0.458 | 0.127 |
| UTIME #14 | 0.440 | 0.126 |
| UTIME #15 | 0.425 | 0.121 |
| UTIME #16 | 0.419 | 0.122 |
| UTIME #17 | 0.437 | 0.128 |
| UTIME #18 | 0.441 | 0.116 |
| UTIME #19 | 0.443 | 0.096 |
| UTIME #20 | 0.413 | 0.123 |

## 3.2 UTIME versus MEQ

Based on independent assessments of the physical, emotional, and cognitive demands of the UTIME questions, these correlations between UTIME and MEQ indicate that higher correlations exist between the scores of the two scales when considering UTIME questions with high cognitive demands and a high executive control component. The rank ordering of the UTIME/MEQ correlations are shown in Table 2. The five highest correlations (#5, #1, #4, #2, and #14) were rated as being most reliant on executive control for successful completion. Conversely, those UTIME tasks independently rated as being associated with emotional control, and as having a low or zero-value executive control component tend to yield a small correlation value with MEQ score. Three of the five lowest correlations (#9, #20, and #19) were rated as being lowest in reliance on planning/reasoning, or executive control. Exceptions to these lowest five are conditions that test inhibitory control – which is a type of executive function – and are discussed below.

Lowered correlations exist between MEQ and UTIME for tasks involving self-assessment of likelihood to succumb to persuasion or being biased (#10, #7, #18). Persuasion is associated with executive control – diminished inhibitory processing is associated with increased ability to be biased or persuaded (Yoon, May, & Hasher, 2000). It would seem that ability to avoid being persuaded or biased should be strongly negatively associated with the MEQ rating – with persuadability being lower at one's peak time-of-day, and vice versa. However only low correlations are reported rather than negative ones.

Physical tasks as presented in the UTIME have varied correlations with MEQ. Independent assessment suggested that some physical activities required greater executive control than others for successful completion (e.g. along with physical skill, #1 requires greater executive control than #6 for successful completion). The correlation data support the independent assessment rating, and suggest that #1 ($r = 0.626$) is more strongly associated with MEQ than #6 ($r = 0.475$).

Table 2. Pearson's correlation (r) between MEQ and UTIME (ranked highest to lowest)

| **UTIME #** | ***r*** |
|---|---|
| 5 | 0.631** |
| 1 | 0.626** |
| 4 | 0.626** |
| 2 | 0.625** |
| 14 | 0.612** |
| 13 | 0.606** |
| 12 | 0.604** |
| 11 | 0.579** |
| 17 | 0.561** |
| 16 | 0.534** |
| 8 | 0.521** |
| 3 | 0.512** |
| 6 | 0.475** |
| 15 | 0.413** |

| | |
|---|---|
| 10 | 0.379** |
| 9 | 0.357** |
| 7 | 0.332** |
| 20 | 0.314** |
| 19 | 0.149 |
| 18 | 0.111 |

** Correlation is significant at the 0.01 level (2-tailed)

## 3.3 UTIME versus MCTQ

The MCTQ is meant to provide four distinct assessments of mid-sleep on workdays, free days, and on free days corrected for sleep duration and for sleep duration and age. Given that I used predominantly individuals from one age group, I did not use the corrected MCTQ measures in our analysis although those data are available for inclusion in expanded experiments. When the MSW and MSF scores each are correlated with the 20 UTIME question scores, the rank ordering of the correlation values indicate the relationship between the perceived performance on the various tasks on work and free days (Table 3). All correlations between UTIME and MCTQ (MSW and MSF) yield negative values, indicating that the outcome scores of each of the two measures are calculated using numbers of opposite value (ie. low UTIME score and high MCTQ score are indicative of an E type person).

Of the highest (top five) UTIME items correlated with MEQ, four of them are in the top five correlated with MSF (#4, #14, #5, and #1). On the other hand, zero of the top five correlated with MEQ are in the top five correlated with MSW. Four out of five of the MEQ correlations correspond to the lowest five for MSF (#20, #7, #19 and #18), and also four for MSW (#7, #19, #18, and #9).

The MSF versus UTIME correlations correspond better with the independent ratings of executive control compared to the MSW versus UTIME correlations. The top five UTIME task independently rated to have the greatest executive control demands (#1-2, #4-5, and #14, all of which are within the top five correlations for UTIME versus MEQ) fall within the top seven correlations between MSF and UTIME. These questions are more scattered in their correlation rank values for UTIME versus MSW. The UTIME tasks independently rated as a low or zero-value executive control component (#7, #9, #18-20, which are within the bottom five correlations for UTIME versus MEQ) fall within the bottom six correlations between MSF and UTIME. These questions are more scattered in their correlation values for UTIME versus MSW. Interestingly, #20 shows the strongest correlation for UTIME versus MSW, suggesting that while possibly not as much associated with one's tendency for morningness or eveningness as rated by the MEQ, #20 may be strongly related with one's sleep or mid-sleep time as rated by the MCTQ (specifically during the work week), and that sleep and one's emotional reactivity may interact to determine one's reaction or performance in such an instance.

Table 3. Pearson's correlation (r) between UTIME and MSW/MSF (ranked highest to lowest)

| **MSW** | | **MSF** | |
|---|---|---|---|
| **UTIME#** | **r** | **UTIME#** | **r** |
| 20 | -0.602** | 4 | -0.576** |
| 3 | -0.535** | 14 | -0.551** |
| 11 | -0.534** | 5 | -0.548** |
| 10 | -0.514** | 11 | -0.542** |
| 16 | -0.494** | 1 | -0.541** |
| 17 | -0.494** | 13 | -0.534** |
| 4 | -0.485** | 2 | -0.497** |
| 14 | -0.482** | 3 | -0.494** |
| 5 | -0.472** | 12 | -0.491** |
| 1 | -0.470** | 17 | -0.488** |
| 8 | -0.454** | 6 | -0.483** |
| 12 | -0.439** | 16 | -0.478** |
| 13 | -0.426** | 8 | -0.473** |

| | | | |
|---|---|---|---|
| 2 | -0.411** | 15 | -0.429** |
| 15 | -0.405** | 9 | -0.337** |
| 6 | -0.389** | 10 | -0.358** |
| 7 | -0.329** | 20 | -0.348** |
| 19 | -0.321** | 7 | -0.269** |
| 18 | -0.319** | 19 | -0.243** |
| 9 | -0.292** | 18 | -0.105 |

** Correlation is significant at the 0.01 level (2-tailed)

## 3.4 MEQ versus MCTQ

MSW and MSF are measures of mid-sleep. The correlations of these two MCTQ values with the MEQ are -0.456 for MSW, and -0.712 for MSF. This suggests that when completing the MEQ, participants responded with their preferences and performance more so on free days than workdays.

Correlations for MEQ versus MCTQ are all negative values. Higher MEQ values, and lower MCTQ values are necessary characteristic of a M type individual and vice versa for an E type individual. Given this inverse relationship between the two scores, it is appropriate to see a negative correlation.

## 3.5 UTIME versus MEQ and MCTQ

The Wilcoxon signed ranks test indicated that the correlation based question ranking of UTIME versus MEQ was most closely associated with the ranking of UTIME versus MSF ($z$ = -0.026, $p < 0.05$, r = -0.004) compared with the other MCTQ ranking (Table 4).

Table 4.a. Wilcoxon signed ranks test output for ranked UTIME vs. MEQ correlations compared to all ranked UTIME vs. MCTQ correlations

| | | **N** | **Mean Ranks** | **Sum of Ranks** |
|---|---|---|---|---|
| ***UTIME vs. MEQ*** | Negative Ranks | 8 | 10.25 | 82.00 |
| **vs.** | Positive Ranks | 10 | 8.90 | 89.00 |
| ***UTIME vs. MSW*** | Ties | 2 | | |
| | Total | 20 | | |
| ***UTIME vs. MEQ*** | Negative Ranks | 8 | 8.56 | 68.50 |
| **vs.** | Positive Ranks | 8 | 8.44 | 67.50 |
| ***UTIME vs. MSF*** | Ties | 4 | | |
| | Total | 20 | | |

Table 4.b. Wilcoxon signed ranks test statistics for the correlation based question ranking of UTIME vs. MEQ, compared to the correlation based question rankings of UTIME vs. MCTQ.

| | ***UTIME vs. MEQ* vs. *UTIME vs. MSW*** | ***UTIME vs. MEQ* vs. *UTIME vs. MSF*** |
|---|---|---|
| ***z*** | -0.153[a] | -0.026[b] |

a. Based on negative ranks
b. Based on positive ranks

# 4 Discussion

The UTIME was developed as a method of dissecting human performance capabilities throughout the day. This is in concert with the current views that daily rhythms of ability can be broadly contained in a concept of morningness versus eveningness. Our general aim therefore was to determine whether existing measures of morningness and eveningness were biased toward particular types of physiological regulation of behaviours over others. UTIME attempts to address abilities and reactions that are determined by varying levels of cognition, physical, and emotional influences.

## 4.1 UTIME correlations with MEQ

MEQ scores are significantly correlated with 18 of the 20 UTIME questions; however, the strength of the correlation varies considerably from 0.631 to 0.111. Overall, tasks with greater executive demands (planning, reasoning) show the highest positive correlations (e.g. #5, #1, and #4), and tasks requiring inhibitory control show the lowest correlations (e.g. #20, #19, and #18). This set of results suggests that the MEQ score is more strongly associated with cognitive tasks that require executive functions such as planning, reasoning, and explicit memory recall. From this viewpoint, M and E chronotypes are individuals whose planning and reasoning skills peak early or late in the day, respectively.

The range of correlations between MEQ score and UTIME question varies considerably. Based on the argument that MEQ measures executive function, I would predict that the degree of correlation for each question would vary with the relative executive function demand for the specific question. Significantly, not all aspects of executive function were strongly correlated with MEQ score. Based on planning and reasoning ability, this relationship is supported by the independent assessment of "executive load" in each question. However, "inhibitory control", or the ability to withhold automatic responses, is also part of executive function. Even though it depends on the way that a question was framed, the ability to control automatic responses should be correlated (positively or negatively) with MEQ. Our finding is that these tasks show the lowest correlations with MEQ.

Existing data (e.g. May, Hasher, & Foong, 2005; Yang, Hasher, & Wilson, 2007) show that automatic responses are higher or more likely at times when inhibitory control is lowest – leading to the prediction of a negative correlation with UTIME tasks that have high inhibitory control demands. However, the lack of correlation between UTIME and MEQ on these tasks may be explained by the fact that the response in question is indeed, automatic. That is, we are not cognitively aware of automatic responses when we perform them (this being the definition of something automatic). If one is not cognitively aware when he or she performs these actions, then how could the individual be sensitive to the time-of-day when he or she most likely produces an automatic response? We recognize the fact that if an individual has knowledge of their lack of cognitive awareness, they may in this case infer a time-of-day when their ability is high or low, but without a visceral understanding of the particular situation.

## 4.2 UTIME correlations with MCTQ

The MCTQ data determines mid-sleep times, and these values are correlated with MEQ scores (Zavada, Gordijn, Beersma, Daan & Roenneberg, 2005). Given this, I expected that correlations would be found between UTIME responses and one or more of the mid-sleep measures. I found a range of correlations among the UTIME questions and mid-sleep times. Higher correlations were found between UTIME and MSF than UTIME and MSW. As with the MEQ, the strongest correlations were for tasks with high executive function. However, the highest correlations with MCTQ were consistently lower than with MEQ. This particular issue is discussed below.

An important issue to address is why UTIME correlations with MSF are consistently higher than with MSW. This similar relationship (in regards to rank ordering of correlations) was also observed with MEQ scores – where MEQ scores are higher than MSF scores. The finding of higher MSF than MSW correlations is especially interesting because UTIME questions (in this version) explicitly ask for reference to work days. The simplest potential explanation for this relationship is that an individual's reported time-of-day preference is not affected by changes in sleep patterns. A major finding from MCTQ responses confirms that sleep patterns change from work to free (e.g. weekend) days. People, (especially E types) tend to be sleep deprived during the week and exhibit a sleep rebound (longer sleep) on the non-work days. Using the MCTQ, this difference can be reported objectively. The MEQ gives an overall preference score, and does not differentiate between preferences on work versus free days. One explanation for this significantly higher correlation between UTIME with MSF than MSW is that time-of-day preference is not affected by the forced change in sleep patterns. That is, people may remember that they were tired on workdays, but the feeling of tiredness does not influence the assessment of time-of-day preference.

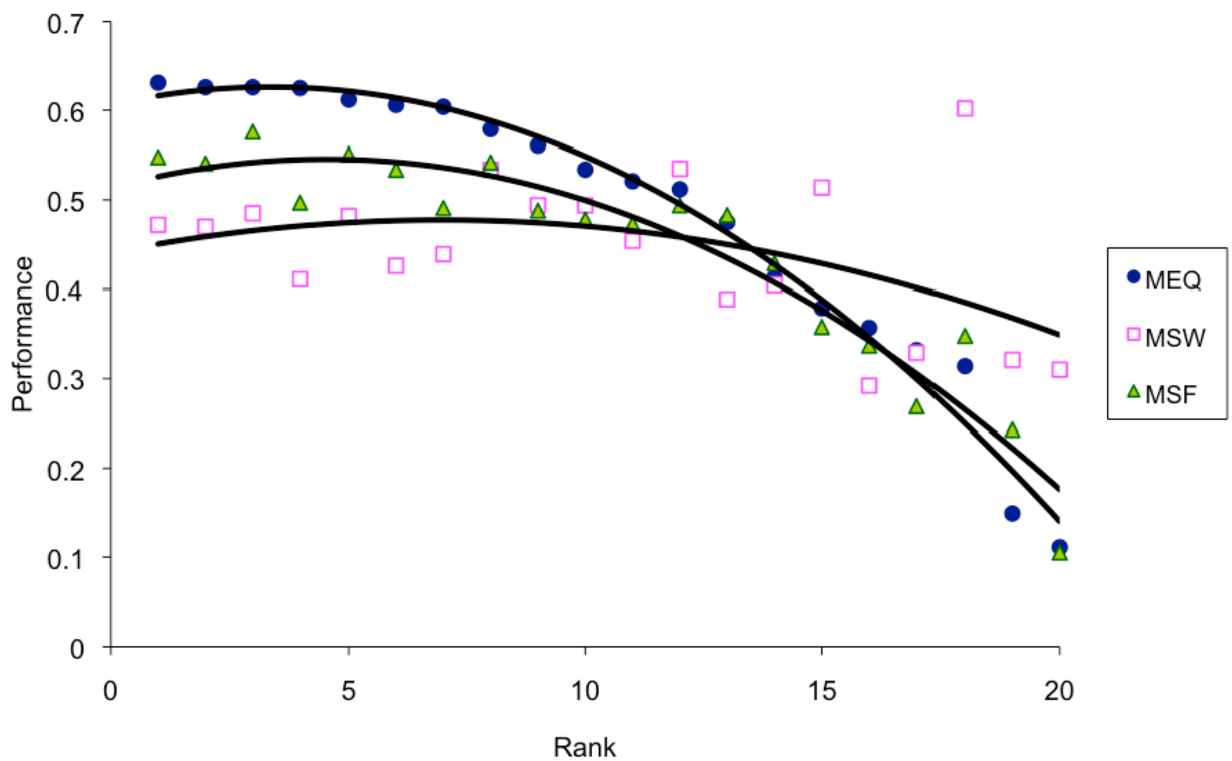
This argument is supported by the UTIME correlation data. Almost all UTIME responses correlate more highly with MSF than with MSW. Therefore, task-by-task, peoples' self-perception of their abilities and responses are more closely associated with their free day sleep patterns. Therefore, sleep, or lack of sleep, may not be a factor, or at least not a significant factor, in determining preference for time-of-day.

To examine this further, I compared the rank ordering of correlations between UTIME and MEQ, MSF, and MSW (Figure 2). Plotting a curve of the ranked correlations between UTIME versus MEQ, and then plotting the same UTIME versus MCTQ questions overtop reflects how the three sets of correlations vary from one another. Ranking the correlations for UTIME versus MEQ provides a relatively smooth curve. The MEQ and MSF curves overlap and remain close to one another at the low correlation end of the graph but are separated from each other at the higher correlation side. Conversely, MSW correlations produce somewhat of a straight line. Neither ends of the MSW curve overlap with either the MEQ or MSF curves. Instead, the MSW points are much more haphazardly scattered across the graph than are the MEQ or MSF points.

The rate of rank decline for MEQ and MSF appear to follow a similar pattern. Conversely, the rate of rank decline for MSW shows no particular resemblance to this rate of decline, and furthermore appears to show little or no pattern for decline at all. It appears then that some aspect of performance on the UTIME questions being asked decreases in a similar fashion in relation to one's MEQ and MSF scores. However, this trend is missing in response to individuals' MSW scores.

The highest score to result between UTIME and MSW ($r$ = -0.602) involved UTIME #20 (Figure 2). When UTIME #20 was correlated with MEQ ($r$ = 0.314), or MSF ($r$ =-0.348), it yielded a much lower correlation. I suggest that while individuals may not have a good awareness of their sleep debt on workdays, they may have an awareness that their level of irritability and emotional reactivity may vary throughout the day as they feel more and less tired, and may understand on some level, their performance will be affected in emotional situations such as those in UTIME #20.

Figure 2. Graph of the UTIME versus MEQ correlation, with UTIME versus MCTQ scores plotted overtop. The $R^2$-values for the trendlines are 0.979 (MEQ), 0.220 (MSW), and 0.913 (MSF), using a second order polynomial.


0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Performance
0
5
10
15
20
Rank
MEQ
MSW
MSF

## 4.3 Underpinnings of UTIME Responses

Independent assessment of the 20 UTIME questions demonstrated that each task required a varying degree of executive control. UTIME tasks were individually designed to test different aspects of daily activities – including cognitively, physically, and emotionally comprised questions. However, while each task may have been more or less oriented to each of these three fields, each required some degree of executive control, and for this reason, independent assessment of each question's executive control component was completed.

Behavioural responses in daily scenarios are controlled by a variety of physical and mental factors that interact with the task's cognitive, physical, or emotional orientation, and executive control demands. Depending on the scenario being presented, an individual's perception of how well he or she will perform may not necessarily be objectively derived (e.g. as would be the case in planning, reasoning, and even some physical tasks), but may be more subjectively determined (e.g. as would be in the case of more emotionally-based situations).

In those situations where one's executive control is diminished, the individual will likely provide more automatic responses. In such cases, an individual may rely increasingly on heuristics, as opposed to more analytic methods of thought. Such may be the case also when one is providing a subjective profile of his or her performance in situations for which they do not have a very objective understanding of how they behaved.

When one must form a subjective opinion, the individual is often likely to make use of heuristics, and may make himself or herself more susceptible to persuasion (Yoon, May, & Hasher, 2000). UTIME questions #7, #10, and #18 concerned the topic of when in the day would the respondent most likely be biased or influenced by some form of media advertisement or other individual. All three UTIME questions generally showed relatively low correlations with both MEQ and MCTQ. However, when one is more alert, there is a greater likelihood that the individual will be better able to objectively, rather than subjectively, process the information being presented to form a less biased decision. I suggest that the low correlations found between UTIME #7, #10, and #18 and the MEQ and MCTQ are the result of participants not being consciously aware that an outside source can bias or persuade them, and rather he or she forming a subjective opinion that they can continue to provide an accurate and morally sound response or reaction even at times when levels of fatigue are higher.

## 4.4 Age and Gender Distribution

Our age distribution was kept relatively close to individuals in their late teens to early twenties (mean age: 20.43 years). I chose not to seek out individuals who were older given that some of the UTIME questions were geared towards university students, as opposed to individuals in the work force, or retired persons with a potentially different schedule. Regarding the lower number of M type or extreme M type individuals noted among the participants, this corresponds with the literature by Hasher, Goldstein and May (2005), and Yoon, May, and Hasher (2000) indicating that only a very small percentage (between 6% and 10%) of younger, university age participants are M type. The authors of these studies found no extreme M types among their participants. Conversely, these authors found that the majority of their participants in this age group classified as extreme E types, E types, and N type. Thus, the results of our research are in accordance with the existing literature.

While the ratio of males to females (7:15) is uneven, previous work indicates that this should not influence the outcome of our results. Adan and Natale (2002) found that women show a greater tendency for morningness than do men. However, Kerkhof (1985) reviewed the literature regarding interindividual differences in the human circadian system and found there to be few and inconsistent difference between men and women. Nonetheless, gender differences in morningness versus eveningness should not influence the results, given that I was not examining how individuals of either gender performed on the MEQ, MCTQ, and UTIME, but rather, on how well one's scores on the various UTIME questions correlate with the MEQ and MCTQ.

## 4.5 Future Directions

Future work should consider time of testing. All current questionnaire packages of the MEQ, MCTQ, and UTIME were completed by participants between the hours of 9:00 am and 6:00 pm; however, the specific time was not recorded. It might be beneficial to understand whether individuals with a M or E type preference show variances in the way they respond across the day, such as whether M or E types show one type of performance response curve for certain activities in the morning, yet provide a different response curve in the evening. Note also that while it would be important to consider of time of testing in the future, the fact that the current study did record time-of-day should not negatively influence our results. The questions asked in the UTIME are free recall, and should be automatic responses about one's self. As noted by Yang, Hasher, and Wilson (2007), under speeded retrieval conditions, automatic responses should show no variance between peak and off-peak retrieval times. While participants who completed our questionnaire package were given no specific time constraint, most finished with forty-five minutes to one hour, and typically had other scheduled engagements such as classes or part-time jobs to attend afterwards.

It should be noted whether participants consume any stimulants (e.g. coffee, or energy drinks) or drugs (either prescribed or illegal) during the day, and or whether the individual suffers from a psychiatric disorder. The use of stimulants or drugs can influences one's sleep patterns, potentially allowing some individuals to rise earlier and or go to sleep later. One may also have more energy to complete various tasks at hours of the day when they would otherwise not have been able to (for example, such as going for a work out late in the evening, or staying up to write an essay in the very early hours of the morning, when they otherwise would have been tired or asleep). Individuals with particular psychiatric disorders such as depression, bipolar disorder, and schizophrenia are known to have skewed circadian rhythms and sleep patterns (Phillips, 2009). Furthermore, such individuals may take medications that affect performance on daily activities, causing them to respond in a potentially skewed manner.

The current set of UTIME questions only considered tasks with negative emotional demands. In future, it will be necessary to correct for this shortcoming of the current study by including questions with positive emotional demands in order to run a comparison between how one's performance varies across the day on negative versus positive emotional tasks.

# 5 Conclusion

Kerkhof and Van Dongen (1996) and Phillips, Chen, and Robinson (2010), defined chronotype by one's preferred sleep-wake time and purport that it is dependent upon one's endogenous circadian rhythm and homeostatic sleep drive. I proposed that it was important to dissect human performance capabilities throughout the day, in order to understand if and when specific behaviours showed rhythmic performance increases and decreases, and to understand the influence of sleep on behaviour. To test this, together with my supervisor, we developed the UTIME, which assesses performance variances throughout the day, as opposed to the currently established measures of chronotype, which suggest that daily rhythms of ability can be broadly contained in a concept of morningness versus eveningness.

Comparison of the UTIME with MEQ demonstrated that the MEQ's definition of morningness or eveningness tendency were heavily based upon one's self-reported peak time-of-day performance on tasks with cognitive, or high executive control demands. Comparison of the UTIME with MCTQ, specifically MSF, showed heighted correlations for tasks whose performance was more influenced by sleep pressures. Furthermore, participants seemed to reflect more so on their performance on a free as opposed to workday schedule.

The UTIME provides a new understanding of chronotype, based on performance capabilities throughout the day. While the MEQ seems to classify individuals as M or E type based on their peak-performance times on tasks with higher cognitive demands and increased executive control needs, the UTIME demonstrates that activities with different demands (such as physical or emotional needs) may be performed best at alternate times than those suggested by the MEQ. Furthermore, UTIME correlations with MCTQ are stronger with the MSF, suggesting that sleep patterns play less of a role in determining chronotype than an individual's circadian rhythm. From these conclusions, I suggest that chronotype depends less so on one's sleep patterns, and more so on one's circadian rhythms.

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# Appendices

Appendix 1a. UTIME questions and performance graph

***For the following questions, please fill out the scale <u>only</u> for the times where you have indicated that you are awake! ***

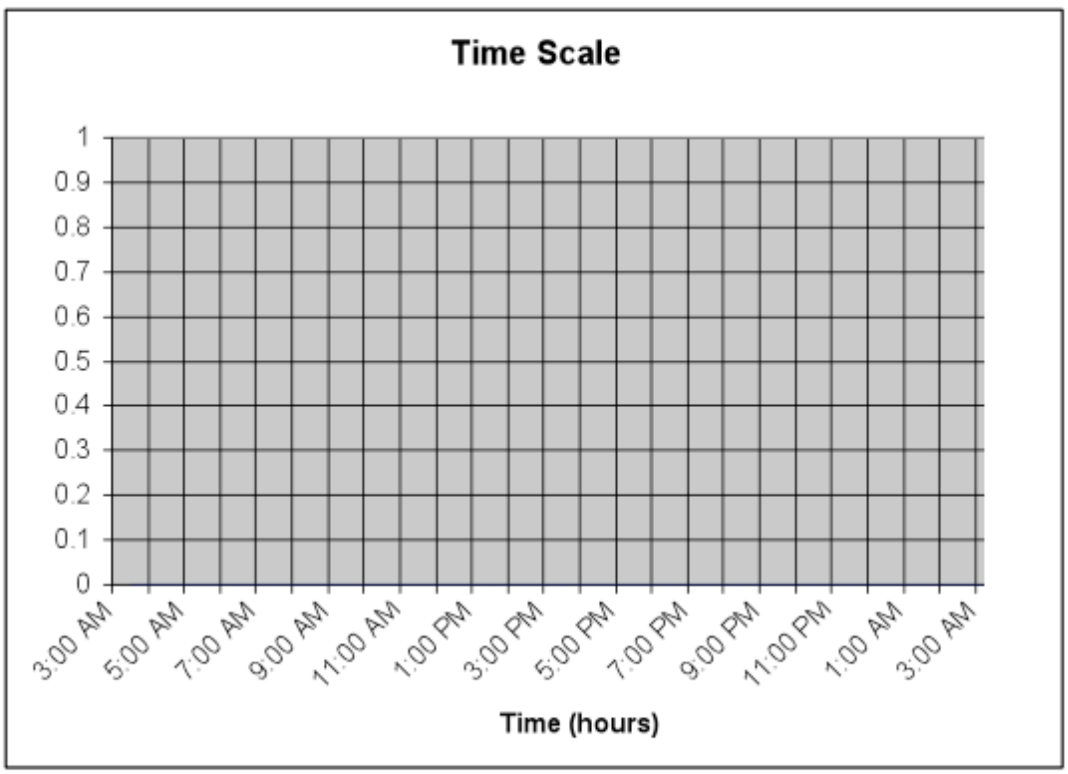
Indicate the time you normally wake up on a **weekday** during your regular work/school week:
__________AM/PM

Indicate the time you normally go to sleep on a **weekday** during your regular work/school week:
_________AM/PM

A) Draw lines marking off your wake-up and going to sleep times
B) Draw a set of points representing you response to the following situation. Use as many points as you need:

1. You are a member of a track team and must run an important race. Indicate at what time-of-day you would perform best, worst, and average at running the race.
2. You must write an in-class multiple choice exam. Indicate at what time-of-day you would perform best, worst, and average on the exam.
3. You are reading a book by one of your favourite authors. Indicate at what time-of-day you would most, least, and somewhat prefer to read the book.
4. You must read and understand a chapter in the course textbook. Indicate what time-of-day would you most, least, and somewhat easily learn the material.
5. You work at an advertising company and must pitch a product for an important deal. Indicate at what time-of-day you would present your most, least, and somewhat persuasive argument.
6. You are going to the gym for your daily workout routine. Indicate what time you would most, least, and somewhat prefer to work out.
7. You are stopped at a stop light and happen to notice a new billboard advertisement has been put up to promote a product. Indicate at what time-of-day you would be most, least, and somewhat persuaded by the billboard advertisement.
8. You must create a piece of artwork as the final project in your art class. Indicate at what time-of-day you would be most, least, and somewhat creative.
9. A close relative has died of natural causes related to old age. Indicate at what time-of-day you would be best, worst, somewhat prepared to face the situation at the funeral home.
10. You are being presented with one side of a new popular ethical issue for which you have yet to determine your own position. Indicate at what time-of-day you would be most, least, somewhat easily persuaded on which position to take on the topic.
11. You are asked to memorize a series of new phone numbers. Indicate at what time-of-day you would be able to most, least, and somewhat accurately memorize the phone numbers.
12. You are asked to work on a jigsaw puzzle in order to win a prize. Indicate at what time-of-day you would most, least, and somewhat quickly assemble the puzzle.

13. You are being interviewed for a position and must convince your potential employer that you are the right person for the job. Indicate at what time-of-day you would give your best, worst, and mediocre performance.
14. You interviewed a set of candidates who applied for a position to work for you. Indicate at what time-of-day you would make the most, least, and somewhat clear-minded decision on who is most suitably qualified for the position.
15. You must give someone negative news. Indicate at what time-of-day you would be most and least able to present the information while maintaining your composure.
16. You are introduced to a new group of people that you have never met before. Indicate when you will remember most, some, and least of their names.
17. You are a court witness and have been asked to recall events of a particular incident. At what time-of-day would you remember most, some, and the least amount of details?
18. You are a court witness and have been asked to recount the details of a particular incident. At what time would a lawyer be most, somewhat, and least likely to bias your recall of specific details?
19. You are going to take a nap. At what time would you be most, somewhat, and least likely to take your nap?
20. You have been waiting in line for a long time to check out of a crowded super market, when someone steps in front of you.  Even if you don't say anything, at what time-of-day are you most and least annoyed by this person's behavior.



Appendix 1b. UTIME example question (a) and sample graph

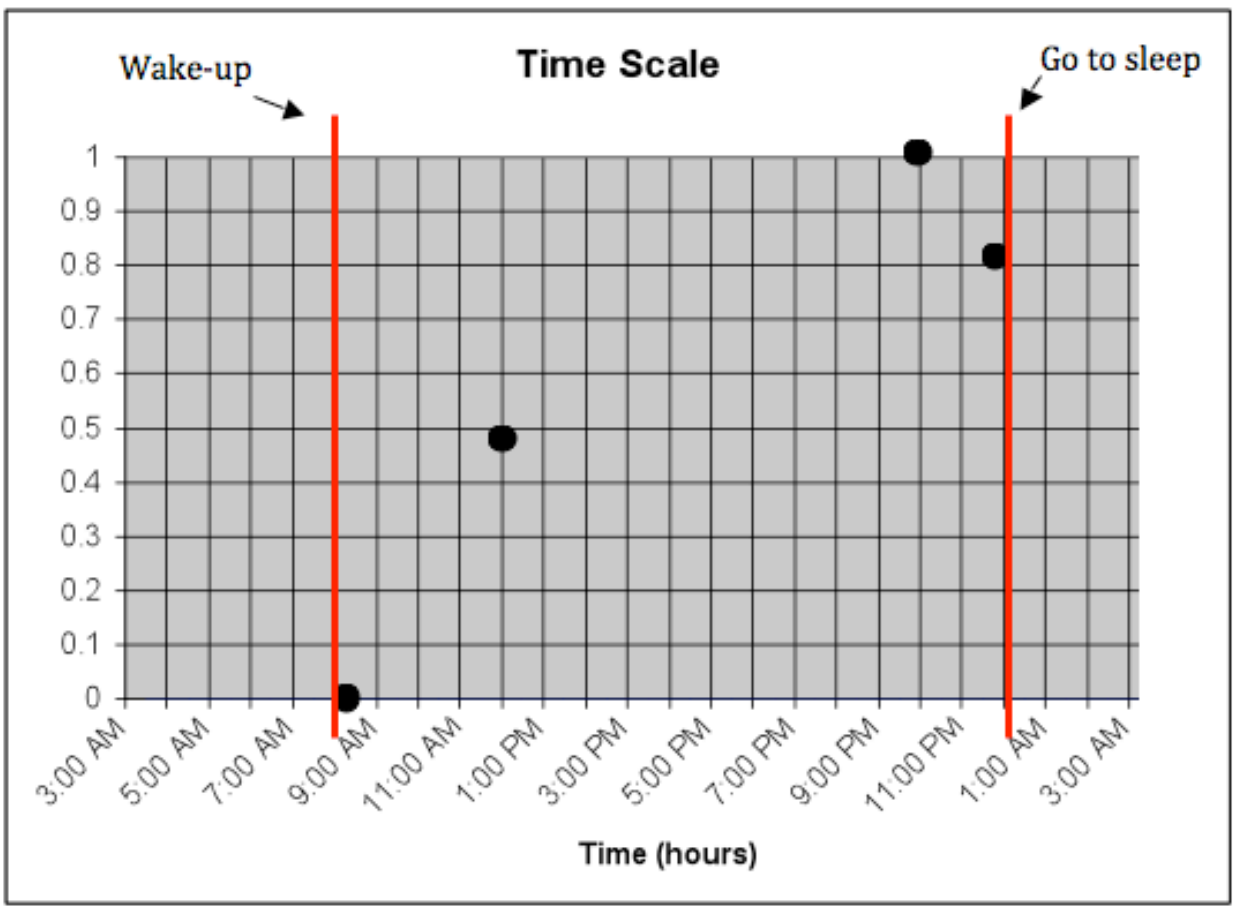
***For the following questions, please fill out the scale only for the times where you have indicated that you are awake! ***

Indicate the time you normally wake up on a **weekday** during your regular work/school week:
_____8____**AM**/PM

Indicate the time you normally go to sleep on a **weekday** during your regular work/school week:
____12____**AM**/PM

A) Draw lines marking off your wake-up and going to sleep times
B) Draw a set of points representing you response to the following situation. Use as many points as you need:

**Your friend is going through an emotional crisis and wants to talk. Indicate how your feelings of empathy might vary through the day and at what times of the day would you be most and least empathetic.**




This person believes he or she will be most empathetic at around 10pm and least empathetic first thing in the morning at about 8am. They become more empathetic during the day. Note that NO ACTIVITY is marked outside of the specified awake period.

Appendix 1c. UTIME example question (b) and sample graph

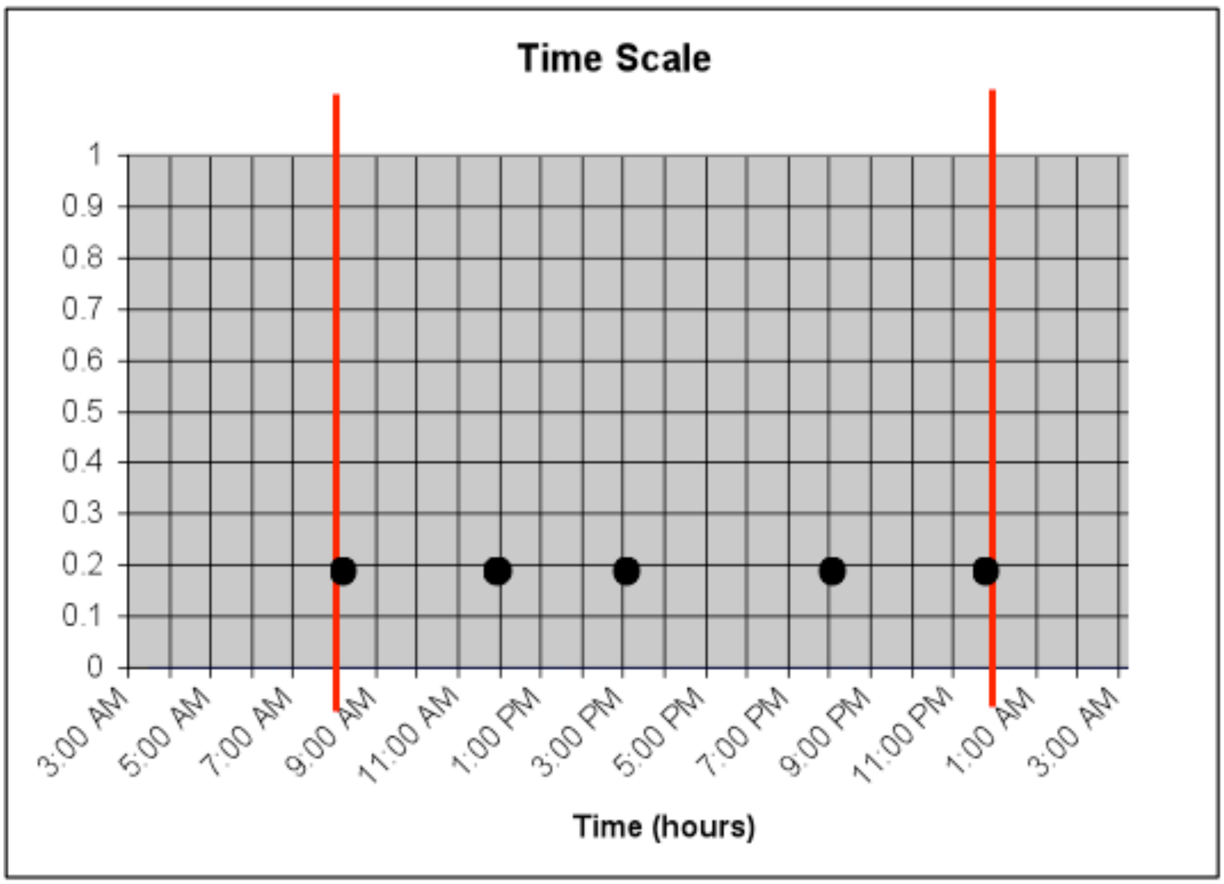
***For the following questions, please fill out the scale only for the times where you have indicated that you are awake! ***

Indicate the time you normally wake up on a **weekday** during your regular work/school week:
_____8____**AM**/PM

Indicate the time you normally go to sleep on a **weekday** during your regular work/school week:
____12____**AM**/PM

A) Draw lines marking off your wake-up and going to sleep times
B) Draw a set of points representing you response to the following situation. Use as many points as you need:

**You are watching a television show and there is a commercial break. Indicate at what time-of-day you would be most, least, and semi persuaded by the commercial**.




This person believes he or she will not be persuaded much by the commercial at any point in the day. Note that NO ACTIVITY is marked outside of the specified awake period.