THE FACE OF SLEEP LOSS

Tina Sundelin
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To dance, for keeping me sane.
Abstract

Sleep deprivation has been studied for over a century, providing knowledge about the benefits of sleep for many physiological, cognitive, and behavioural functions. However, there have only been anecdotal indications about what a tired or sleep-deprived person looks like, despite the fact that appearance influences not only how other people perceive a person but also how they evaluate them and behave towards them. How someone with sleep loss is perceived and evaluated by others is the focus of this thesis. Facial photographs of 48 participants were taken after normal sleep and after either one night of total sleep deprivation or two nights of partial sleep deprivation. The photographs were then evaluated in four different studies by a total of 288 raters recruited from universities and the general public in Stockholm, Sweden. The faces were rated on attractiveness, health, tiredness, sleepiness, sociability, trustworthiness, employability, and leadership ability. These factors were all adversely affected by sleep loss. Furthermore, looking tired was strongly related to being less attractive, looking less healthy and less trustworthy, and being perceived as a poorer employee and leader. One of the studies assessed facial features commonly associated with looking tired, showing that sleep deprivation results in eyes which appear more swollen and red, with dark circles and hanging eyelids, as well as paler skin with more fine lines and wrinkles. When sleep deprived, people were also perceived as more sad. In conclusion, the four studies show that sleep loss and a tired appearance affect how one is perceived by other people. These perceptions may lead to negative evaluations in interpersonal situations, both personal and professional. This thesis thus demonstrates social benefits of prioritizing sleep, adding to the physiological, cognitive, and behavioural research on sleep loss.

Keywords: sleep loss, sleep deprivation, face perception, interpersonal perception, attractiveness, tiredness
Svensk sammanfattning


Denna avhandling består av fyra studier som söker svara på frågan om hur andra personer uppfattar någon som inte har sovit ordentligt. I ett första steg har fotografier tagits på 48 personers ansikten efter åtta timmars sömn och efter olika grad av sömnbrist. Ansiktena på fotografierna har sedan utvärderats av 288 bedömare gällande attraktivitet, hälsa, trötthet, sömnighet, sällskaplighet, pålitlighet, anställningsbarhet och ledarskapsförmåga. Dessa utvärderingar visade att när man inte har sovit uppfattas man som lite mindre attraktiv, mindre frisk, mindre pigg, mindre pålitlig, mindre anställningsbar och som en sämre ledare jämfört med när man har fått tillräckligt med sömn. Dessutom var bedömarna lite mindre intresserade av att umgås med någon som inte hade sovit. Att se trött ut var också starkt kopplat till mer negativa utvärderingar på samtliga av dessa frågor. Vidare visades att sömndepriverade personer uppfattas ha mer röda och svullna ögon med mörka ringar och hängande ögonlock, samt blekare hud och mer rynkor. De såg även lite ledsnare ut än när de hade sovit.

Efter en natts sömnbrist eller ett par nätter med minskad sömn ökar alltså risken för att bli uppfattad bland annat som mindre frisk och som en sämre ledare. Andra vill dessutom mindre gärna umgås med någon som inte har sovit jämfört med när samma person är utvilad. Detta gäller speciellt om man, efter att inte ha sovit, ser väldigt trött ut. De sociala aspekterna av sömnbrist har inte studerats i särskilt stor utsträckning tidigare, men dessa studier visar på betydelsen av att kombinera forskning inom sömn och socialpsykologi. De bidrar också med ännu en anledning att prioritera sin sömn, utöver de redan etablerade kognitiva, immunologiska och metabola sådana.
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A wise recent PhD graduate once told me that one needs good people to go through this process with, and I feel incredibly lucky to have had some really great people by my side. So a particular thank you to past and present PhD students Kristina Karlsson, Ingrid Stanicu, Maria Öhrstedt, Lisa Folkesson, Stefan Annell, Gustaf Törngren, Diana Sanchez Cortes, Elmeri Syrjänen, Jelena Corovic, Natalie Peira, Veit Kubic, Andrea Niman, Anna Lindqvist, Azade Azad, Constanze Eib, Jesper Alvarsson, Malin Mattson, and Aram Seddigh for the eminent company.

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Early in my fourth year as an undergraduate, I stopped by the boyfriend's house on my way home from class, raving as usual about all the interesting
things I had just learned. He said, casually, "you should be a professor, you're so passionate about all this stuff". The thought had never occurred to me, but the more I considered it, the more sense it made. So thank you Len, for planting that first seed that led me here.

To my friends outside of academia, both near and far, thank you for never making me talk about my "bullshit" research but always listening intently when I do. And for everything else.

And finally, to my family: words cannot express even a fraction of my gratitude for your endless support and love.
List of studies

The present doctoral thesis is based on the following studies:


III. Sundelin, T., Lekander, M., & Axelsson, J. (Submitted). The effects of restricted sleep on facial appearance and social appeal.

IV. Sundelin, T., Garke, M., Svensson, I., & Axelsson, J. (Submitted) Sleep in and get the job: The effect of sleep restriction on perceived employability and leadership ability.

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Introduction

Every day you make choices that affect your life in one way or another. You decide to take the subway or walk, go to a party or stay at home, get a good night's sleep or watch another episode (or four) of the show you are into right now. Some choices have more lasting consequences than others; walking gives you fresh air and exercise, which is good for your health. Some may have a bigger impact than you had ever imagined; at the party, you end up meeting the love of your life. And some of the choices become habit, without much thought as to what the options really are; just watch another few episodes, you can always sleep tomorrow... Right?

This thesis is about that last choice. When you stay up doing important (or inconsequential) things, robbing yourself of necessary shuteye, it affects you in more ways than you might think.

The importance of sleep

At least since the late nineteenth century, researchers have been interested in the functions of sleep (Patrick & Gilbert, 1896). Assuming it was important for something, knowing that some animals eventually die if they are kept awake for too long (Siegel, 2008), one way to look for answers was — and still is — to deprive people of it. Some of the oldest human sleep-deprivation studies focused on 1-7 individuals who stayed awake for 72-264 hours (Bliss, Clark, & West, 1959; Kollar et al., 1969; Patrick & Gilbert, 1896). It is not always entirely clear what the hypotheses were, but subjects were measured on everything from urine composition and reaction time, to visual hallucinations and recovery sleep. Our knowledge about sleep and the effects of sleep deprivation has increased substantially since then, although the question of why we need sleep does not seem to have just one answer.

There are several theories attempting to explain what the main function of sleep is. Some focus on the synapses of the brain, highlighting the need for synaptic homeostasis and suggesting that less important connections are pruned during sleep (Tononi & Cirelli, 2006), whereas those which need to be maintained are reorganized (Krueger, Obal, Kapas, & Fang, 1995). This
would be of crucial importance to learning and memory, which are arguably some of the most essential facets of human life. Others emphasize the role of sleep in restoration of the body, for example through lowering the core temperature in order to decrease cerebral metabolism, facilitate immune processes, and protect against overheating of the brain (McGinty & Szymusiak, 1990). It has also been pointed out that sleep may help clear out toxins from the brain (Xie et al., 2013) and that skin blood flow increases while sleeping, possibly enhancing the body's first line of defense against pathogens by improving skin function (Van Someren, 2006). A less mechanistic theory is that of sleep being instrumental in optimizing behaviours, such as staying out of possible predators' way or conserving energy when foraging is suboptimal (Berger & Phillips, 1995; Siegel, 2009). It is unlikely that we will ever be able to discern just one main evolutionary reason for why we sleep, but there are definitely many benefits of sleeping. At the very least, when you get a good night's sleep you avoid the negative effects of not sleeping.

Unfortunately, sleep problems are quite common these days, with up to 21% of people across several Western countries reporting difficulties falling or staying asleep often or always (Ohayon, 2002). Although actual mean sleep duration may not have had the steady universal decline some scholars suggest (Bin, Marshall, & Glozier, 2012; Knutson, Van Cauter, Rathouz, DeLeire, & Lauderdale, 2010), population-based studies in Finland and the USA indicate that among full-time workers, sleep time has decreased approximately 18 minutes over the past 30 years (Kronholm et al., 2008) and this group is more likely to be short sleepers (sleeping 6h or less) than others (Knutson, et al., 2010). If you work longer hours, you also tend to sleep less (Knutson, et al., 2010; Virtanen et al., 2009). In Sweden, work-related sleep disturbances increased during the 1990-ies (Westerlund et al., 2008) and in 2010 the proportion of people who reported sleep problems was around 26-27%, across all age groups (Socialstyrelsen, 2014). Therefore, regardless of whether sleep duration has declined over time, there seems to be a common dissatisfaction with the amount of sleep we are getting. And even just a night or two of sleep loss (such as those familiar to many university students, parents, and dedicated careerists) has ramifications beyond feeling sleepy the next day.

Since those first few studies on sleep deprivation, thousands of people have been kept awake in order to still the curiosities of researchers, as well as to provide knowledge about sleep problems and their consequences. The results have usually not been encouraging for those of us who "forget" to prioritize sleeping, or struggle with involuntary sleep loss. Ranging from physiological to societal, the negative effects of acute and chronic sleep loss are
abundant and, as such, should provide a strong argument for prioritizing sleep.

Effects of sleep loss

Whether it is one night of total sleep deprivation, or more chronic sleep restriction, the immune system seems to take a beating from sleep loss. For example, staying awake for 48 hours straight (Ozturk et al., 1999), or just sleeping less than 7 hours for one night (Fondell et al., 2011), results in fewer, less active, Natural Killer cells. These cells are part of the body's primary line of defence against pathogens, both fighting off viral infections and slowing the progression of cancer (Vivier et al., 2011). As it turns out, people who on average sleep less than 7 hours per night have an almost tripled risk of developing a cold after exposed to a rhinovirus (Cohen, Doyle, Alper, Janicki-Deverts, & Turner, 2009). Sleep loss also affects the metabolic system (Spiegel, Leproult, & Van Cauter, 1999), with chronic sleep problems increasing the risk of obesity (Markwald et al., 2013), and developing type 2 diabetes (Knutson, Spiegel, Penev, & Van Cauter, 2007) as well as cardiovascular diseases (Cappuccio, Cooper, D'Elia, Strazzullo, & Miller, 2011; van Leeuwen et al., 2009).

On top of paying physiologically for not sleeping, other aspects of our everyday functioning are affected as well. If one wants an optimal level of attention, learning, working memory, and/or cognitive control, sleep loss is not the way to go (Killgore, 2010; Lim & Dinges, 2010). Moreover, the growing body of evidence for how sleep deprivation affects the way we relate to, and behave in situations with others is of interest for a social species such as ours. Staying awake for 30-36 hours makes you more reactive to emotional stimuli (Gujar, Yoo, Hu, & Walker, 2011; Yoo, Gujar, Hu, Jolesz, & Walker, 2007), less able to recognize ambiguous emotions in photographed faces (van der Helm, Gujar, & Walker, 2010), and less willing to trust an anonymous person to do the right thing (Anderson & Dickinson, 2010). One night of sleep deprivation impairs emotional empathy (Guadagni, Burles, Ferrara, & Iaria, 2014), which is also exemplified by natural sleep variation showing an association between poor sleep and less empathic accuracy and conflict resolution in romantic couples (Gordon & Chen, 2013). Two nights of sleep deprivation might increase the tendency to direct blame away from oneself, decrease the willingness to offer an apology (Kahn-Greene, Lipizzi, Conrad, Kamimori, & Killgore, 2006), and make it harder to decide what is moral and what is not (Killgore et al., 2007) – at least for a group of American military personnel. Reducing nightly sleep to 4 hours for a week and a half decreases self-reported optimism and sociability,
which is hardly surprising considering how drowsy and worn out people on this kind of sleep schedule also report feeling (Haack & Mullington, 2005).

As if this was not enough, take a brief moment to consider how your lapses in attention, feeling drowsy, and even nodding off might affect more people than just yourself, your co-workers, and your loved ones. Any job in which you are responsible for operating a vehicle or heavy machinery often comes with a continuous demand for alertness and vigilance, abilities which are heavily impaired in sleep-deprived people (Lim & Dinges, 2010). Sleepiness and lack of sleep are highly correlated with manmade errors and accidents in industrial settings as well as in the transport industry (Dinges, 1995; Philip & Akerstedt, 2006). We definitely do not want sleepy individuals flying planes, driving buses, or being responsible for nuclear power plants.

Fortunately, nearly all of these effects of sleep loss are easily reversible. Natural Killer cells and metabolic hormones are back to normal after a night of recovery sleep (Ozturk, et al., 1999; Spiegel, et al., 1999), as are cognitive control (Drummond, Paulus, & Tapert, 2006) and feelings of optimism and sociability (Haack & Mullington, 2005). But some of the effects on cognitive abilities, sleepiness, and the immune system take longer to normalize (Banks, Van Dongen, Maislin, & Dinges, 2010; Lasselin, Rehman, Akerstedt, Lekander, & Axelsson, 2014), and chronic consequences such as diabetes and heart disease are more difficult to undo once they have developed, regardless of how well you sleep. Furthermore, accidents are rather impossible to reverse, as are poor performances at work, as well as other people’s first impressions of you. In conclusion, sleep is important and although you may be able to "catch up" on what you have missed, some ramifications could be permanent.

Studying sleep loss

As noted in the previous section, studies on sleep vary a lot in how that main variable is manipulated. Some focus on self-reported or objectively assessed natural variations, others compare people with clinical sleep problems to those without. In experimental designs, a common distinction is that of total sleep deprivation and partial sleep deprivation (sleep restriction) but even within these two branches there are variations. Total sleep deprivation is most commonly enforced for one night, resulting in approximately 30-36 hours awake. As mentioned earlier, some studies go even further, forcing their subjects to stay awake for 2.5 days or longer. The latter may show more severe effects of not sleeping, but lack ecological validity for most people. Other studies, focusing on chronic sleep loss and thus trying to
achieve a bigger generalizability, restrict or fragment their participants' sleep for one or several nights. In turn, restricted sleep can be due to going to bed later or waking up earlier, and sleep fragmentation can focus on total sleep or on particular sleep stages. These are all valid ways of learning about the functions of sleep and each of them adds their piece to the puzzle. The approach taken will depend on the question asked and whether one is trying to draw conclusions about sleep mechanisms or about how certain sleep schedules affect people's everyday lives. That being said, several nights of sleep restriction may actually produce similar effects to total sleep deprivation (Van Dongen, Maislin, Mullington, & Dinges, 2003).

When studying sleep loss, one should also keep in mind the variation in how much sleep people feel they need (e.g. Ursin, Bjorvatn, & Holsten, 2005), as well as the large, stable individual differences in how people react to not sleeping (Leproult et al., 2003). These differences seem to be at least partially based in our genetic makeup (Viola et al., 2007), with certain genotypes being affected more than others, for example regarding executive functions (Groeger et al., 2008) and sustained attention (Retey et al., 2006). The effect of sleep loss on attention is also dependent on age, such that older people seem slightly less vulnerable than younger people (Adam, Retey, Khatami, & Landolt, 2006). Furthermore, not all domains are affected the same way within the same person. You can be worse at cognitive processing but not feel very sleepy, or your attention may be impaired but your cognitive processing ability less so (Van Dongen, Baynard, Maislin, & Dinges, 2004). Sleep manipulations may thus show different effects in different people, depending on their genetic makeup, how well they cope with not sleeping, and what kinds of tests they perform following the sleep loss.

Tiredness, sleepiness, and fatigue

The distinction between the concepts sleepiness, tiredness, and fatigue may seem artificial for anyone who goes to sleep when they feel tired or describes themselves as fatigued after staying up all night. They are certainly used interchangeably both in everyday speech and in many clinical and research settings, even by those who work with people with these kinds of complaints (Hossain et al., 2005; Shen, Barbera, & Shapiro, 2006). Nonetheless, when looking more closely at their meanings, and deciding which to measure and why, the distinction becomes an important one. The general consensus among researchers is that fatigue and sleepiness are conceptually different, with tiredness considered either an overarching category or more or less synonymous with fatigue (Dittner, Wessely, & Brown, 2004; Shen, et al., 2006). However, fatigue is sometimes also defined as "extreme, and
persistent tiredness, weakness or exhaustion" (Dittner, et al., 2004), suggesting it may be seen as a clinical, chronic form of tiredness. Others consider fatigue a multidimensional concept, including general fatigue, physical fatigue, mental fatigue, reduced motivation, and reduced activity (Smets, Garssen, Bonke, & De Haes, 1995). Mental fatigue, or cognitive fatigue, can be defined as feeling mentally tired (Akerstedt, et al., 2004) and is also used to describe the state of cognitive depletion one is in after sustained mental effort (e.g. van der Linden, Frese, & Sonnentag, 2003). For example, spending a long time trying to sustain attention results in this kind of fatigue (Boksem, Meijman, & Lorist, 2005; Lim et al., 2010).

Sleepiness, on the other hand, is often referred to as a "stable physiological tendency to fall asleep" (Dement & Carskadon, 1982, p.58) and "an increased propensity to doze off or fall asleep" (Shahid, Shen, & Shapiro, 2010, p.81). But subjective sleepiness can decrease through physical activity, social interactions, and bright light, and tends to increase during boring tasks which include sustained attention (Akerstedt, Anund, Axelsson, & Kecklund, 2014), just like fatigue. Therefore, thinking of sleepiness as just an increased sleep pressure (Akerstedt & Folkard, 1995) does not cover the whole picture. For example, subjective measures of daytime sleepiness do not correlate well with the time it takes to fall asleep (Chervin & Aldrich, 1999; Johns, 2000). Moreover, neither of these definitions take into account the drowsiness or sleep inertia one might experience after just waking up (Shen, et al., 2006). Some researchers see sleepiness as an extreme version of tiredness, finding that the main difference between people's experiences of the two lies in the heaviness of one's eyelids (Dement, Hall, & Walsh, 2003).

To further complicate things, there are some scales where sleepiness is considered a dimension of fatigue (Ahsberg, 2000), and although alertness is often used as the opposite of sleepiness (Akerstedt & Gillberg, 1990; Hoddes, Zarcone, Smythe, Phillips, & Dement, 1973), it actually has a stronger correlation with self-rated fatigue than with self-rated sleepiness (Hossain, et al., 2005). When referring to fatigue as the consequence of sustained attention, or time-on-task, it is further exacerbated by sleep deprivation (Lim & Dinges, 2008). In other words, alertness may be at the other end of the spectrum from doing boring, sleep- and fatigue-inducing tasks.

There also appear to be some linguistic differences. In Finnish, the word "väsymys" may refer to both sleepiness and exhaustion (Martikainen, Hasan, Urponen, Vuori, & Partinen, 1992), whereas in German, as in Swedish, tiredness can be used to indicate sleepiness but not necessarily the other way around (Schneider, Fulda, & Schulz, 2004). One example of this difference,
and of tiredness being a ubiquitous word in Swedish, is the translation of the
Fatigue Severity Scale (Krupp, LaRocca, Muir-Nash, & Steinberg, 1989), in
which all instances of the word "fatigue" in English have been translated to
"trötthet" (i.e. tiredness) in Swedish (Mattsson, Moller, Lundberg, Gard, &
Bostrom, 2008).

The studies in this thesis have used tiredness and fatigue interchangeably, in
the form of the Swedish word "trötthet". Sleepiness, on the other hand, has
been considered a different construct; one more closely related to sleep pro-
pensity and drowsiness. The corresponding Swedish word is "sömnighet".

Perceiving sleep loss in others

The sleep-deprived individual might thus be feeling sleepy, tired, and/or
fatigued, but can this be perceived by others? The tendency for a changed
facial appearance after sleep deprivation was reported already 50 years ago.
According to West, Janszen, Lester, & Cornelison (1962), sleep-deprived
participants' faces "become elongated and immobile; the brow is furrowed
with the effort to hold open drooping lids during drowsy periods of growing
intensity" and "During periods of greater alertness there is a hollow-eyed,
suspicious stare" (p.68). Although these descriptions do not quite qualify as
empirical evidence, they indicate that there may be a perceivable change in
appearance after sleep deprivation. Few studies have attempted to quantify
this change, although dynamic appearance, specifically regarding facial in-
dicators of drowsy driving, has been researched from an accident-prevention
angle. Trained raters are able to evaluate whether a driver is drowsy based
on a video of the driver's face, where longer eyelid closures seems to be the
most reliable cue (Wierwille & Ellsworth, 1994). People might also be able
to tell that someone is sleep deprived based on how they speak. When read-
ing a story, sleep-deprived individuals were rated as sounding more fatigued
and using less appropriate intonation compared to when they had slept
(Harrison & Horne, 1997). But other than intonation in story-telling, and
eyes closing while driving, there has not been much interest in whether we
can accurately perceive others' sleep history, nor their tiredness/fatigue or
sleepiness.

There are three studies in which evaluations of photographs have included
sleepiness or fatigue. In one of them, a Japanese team instructed actors to
imagine when "...you feel asleep/feel bored/are full/are on a train/are in
class" respectively (T. Fujimura, personal communication, February 4, 2015)
and filmed them while expressing the "emotion" sleepy (Fujimura & Suzuki,
2010). The other emotions filmed were angry, fearful, surprised, sad, calm,
excited, and happy. Participants were instructed to choose which of these emotions was displayed, based on the short film or based on a photograph taken from the film. The accuracy for sleepiness was 77% and there was no difference between the dynamic and the static expression. This suggests that we have a stereotypical idea of what sleepy looks like; one that we are able to convey to each other through facial expressions. But whether this expression constitutes a face after sleep loss or whether it is just assumed to show sleepiness, based on extrapolations from how people look when they are about to fall asleep, remains to be seen. Furthermore, the authors fail to specify what exactly the features of "sleepy" might be, despite referring to Ekman and Friesen's (1976) particular muscle actions for all the other expressions.

The second study focused on eye-tracking, measuring where participants looked when instructed to rate people's fatigue (on a scale from not tired to most tired) and age from facial photographs (Nguyen, Isaacowitz, & Rubin, 2009). The people in the pictures were "normal appearing" (p.356) patients from a surgery image database. The authors found that participants spent more time looking at the eyes than anywhere else, both when instructed to rate fatigue and when instructed to rate age. They conclude that surgery to the eye region may increase facial attractiveness by decreasing the appearance of old age and tiredness. Indeed, several plastic surgeons suggest a tired face consists of droopy eyelids and dark circles under the eyes (Duncan, 2004; Fanous, 1983), and that removing these can increase the attractiveness of a face.

Finally, there is one study in which the goal was to elucidate the role of the eyelids and eyebrows in different expressions, among them tiredness. The authors manipulated eyelid length and droopiness, and eyebrow elevation, by digitally altering a photo of the upper half of a female face (Knoll, Attkiss, & Persing, 2008). The pictures were evaluated by 20 healthcare workers who perceived tiredness, and often sadness, in the faces that had droopy, longer, or more prominent eyelids.

Interestingly however, there is no previous research investigating whether sleep loss leads to a tired or sleepy appearance, nor whether someone who looks sleep deprived or tired is actually perceived as less attractive, as suggested by Nguyen et al. (2009).
Evaluating faces

Facial appearance may seem like an arbitrary focus of study, compared to the multitude of seemingly more important factors that could be used to evaluate a person, such as intelligence, attitudes, socioeconomic status, and personal interests. However, considering how apt we are at understanding others' facial expressions (Ekman et al., 1987) and how, from infancy, we prefer faces over other stimuli (Morton & Johnson, 1991), maybe we should not be too quick to disregard the impact of facial appearance. In fact, there are several brain regions whose primary activity seems to be the processing of faces and their role in social communication (Haxby, Hoffman, & Gobbini, 2000), indicating that we spend a lot of physiological resources on this. There are also many studies suggesting that facial appearance influences which traits others expect a person to possess (Todorov, Olivola, Dotsch, & Mende-Siedlecki, 2015), which in turn influences the behaviour of both the perceiver and the perceived (Snyder, Tanke, & Berscheid, 1977).

Attractiveness

One of the most studied aspects of facial appearance is attractiveness, shown to be implicated in everything from mate-choice (Rhodes, Simmons, & Peters, 2005) and parental care (Langlois, Ritter, Casey, & Sawin, 1995) to the persuasiveness of advertisements (Praxmarer, 2011). Although we might like to think beauty is in the eye of the beholder, the generally held view is that faces which are symmetric, average, and sexually dimorphic are more attractive than those that are not (e.g. Grammer, Fink, Moller, & Thornhill, 2003; Rhodes, 2006). Furthermore, faces that look trustworthy (Todorov, et al., 2015), young (Ebner, 2008), and healthy (Jones et al., 2001; Kalick, Zebrowitz, Langlois, & Johnson, 1998) are also more attractive. There is wide agreement to the reasoning that an evolutionary advantage is behind appreciating these factors. This reasoning suggests that it is beneficial to want to be around people who are trustworthy and healthy, and to mate with fertile (i.e. youthful) people who have the best genes, in other words those whose symmetry and averageness have not been affected by incest, developmental diseases, or parasites (Rhodes, 2006; Thornhill & Gangestad, 1999).

The question of whether attractive people actually are healthier is still being debated (Dykiert et al., 2012; Grammer, Fink, Moller, & Manning, 2005; Henderson & Anglin, 2003; Kalick, et al., 1998; Kramer & Ward, 2010; Nedelec & Beaver, 2014; Shackelford & Larsen, 1999; Weeden & Sabini, 2005; Zebrowitz & Rhodes, 2004), but health is not the only trait we attribute to those who are good looking. In a seminal study from 1972, Dion and colleagues found support for the stereotype that "what is beautiful is good", ..
showing that physically attractive people were ascribed a more socially desirable personality and were expected to be more successful both in their social and occupational life compared to unattractive people (Dion, Berscheid, & Walster, 1972). Several follow-up studies have confirmed this stereotype, or halo effect, concluding that although attractive people are no more competent or sociable than others (Feingold, 1992), they are consistently seen and treated as such (Langlois et al., 2000). Further examples of this preferential treatment can be found in research on employment decisions and political voting behaviour. All else being equal, attractive people are more likely to get hired (Dipboye, Fromkin, & Wiback, 1975; Gilmore, Beehr, & Love, 1986) as well as elected for office (Banducci, Karp, Thrasher, & Rallings, 2008; Berggren, Jordahl, & Poutvaara, 2010; White, Kenrick, & Neuberg, 2013).

Health

We know from the previous section that attractive people are perceived as more healthy, which is also true for people with symmetrical faces (Grammer & Thornhill, 1994; Jones et al., 2004), and people whose faces contain neither a lot of, nor very little, fat (Coetzee, Perrett, & Stephen, 2009). Another factor that influences a face's appearance of health is colouration, specifically the red tint that comes with oxygenated blood close to the skin (Stephen, Coetzee, Law Smith, & Perrett, 2009). It has also been shown that when participants can modify photographs to enhance the health of a (Caucasian) face, they increase the levels of red (vs. green) and yellow (vs. blue), and make it look lighter rather than darker (Stephen, Law Smith, Stirrat, & Perrett, 2009). The implication here is that in addition to blood perfusion, carotenoids and melanin may have an impact both on a healthy appearance and actual health.

When it comes to perceiving health in others, there seems to be a relationship with actual health (at least when controlling for attractiveness) (Kalick, et al., 1998; Little, McPherson, Dennington, & Jones, 2011). But whether or not our perception of health in others’ faces is accurate or not, it is bound to affect how we behave towards them. It would of course be evolutionarily beneficial to stay away from people who are contagious, and a few studies have suggested mechanisms for this kind of avoidance. For example, people with a recently activated immune system smell worse than those without such an activation (Olsson et al., 2014). Also, just looking at pictures of germs or people coughing leads to decreased ratings of extraversion (Mortensen, Becker, Ackerman, Neuberg, & Kenrick, 2010) and increased ratings of disgust (Schaller, Miller, Gervais, Yager, & Chen, 2010), which may further promote withdrawal. But even when there is no real disease
threat, a healthy appearance seems to be a big asset. For example, people who move in a way that makes them look healthy may have a bigger chance of becoming president or prime minister (!) (Kramer, Arend, & Ward, 2010).

Sleep loss and appearance
There are decades worth of studies on the effects of sleep loss and an abundance of research on facial appearance, but hitherto these two fields have not been combined in a systematic way. We have thus arrived at the main topic of this thesis: are there compelling reasons to believe that sleep loss would affect one's appearance? The notion of beauty sleep, for example, has been around since the 1850-ies, originally referring to the hours of sleep before midnight (Harper, 2001-2014) "on the assumption that early hours conduce to health and beauty" (Farmer & Henley, 1909, p. 172). This, along with the anecdotal observations of previous generations of sleep researchers, gives us a colloquially grounded conclusion that it might.

Considering the agreement among Japanese actors and raters on what "sleepy" looks like (Fujimura & Suzuki, 2010), we might be able to tell just by looking at someone's face that they have not slept well. This hypothesis is also derived from the fact that sleep loss affects your immune system and makes you more susceptible to infectious diseases. If health status is visible in one's face, and also affected by sleep loss, then sleep loss could be visible as well, by association. One way in which this could manifest is through skin function, considering that allergic skin responses are aggravated and skin barrier function is impaired after a night of sleep deprivation (Altemus, Rao, Dhabhar, Ding, & Granstein, 2001; Kimata, 2002). There is also a tendency for acne to be negatively affected by poor sleep quality (Chiu, Chon, & Kimball, 2003). Having healthier-looking skin is related to being more attractive (Jones, Little, Burt, & Perrett, 2004; Jones, Little, Feinberg, et al., 2004), as is having more smooth skin (Fink, Grammer, & Thornhill, 2001). Thus, sleep-related decreased health could be noticeable in a face, and would likely also affect attractiveness.

When it comes to what it might be about a face that makes it look tired and sleep-deprived, previous studies provide little information. The main clues are that progressively droopy eyelids increase perceived drowsiness (Wierwille & Ellsworth, 1994), and dynamic cues such as blink speed, duration, and amount correlate with sleepiness (Ingre, Akerstedt, Peters, Anund, & Kecklund, 2006) and time awake (Anderson, Chang, Sullivan, Ronda, & Czeisler, 2013). These cues also predict lapses in sustained attention (Ftouni, Rahman, et al., 2013) as well as sleep-related traffic incidents (Ftouni,
Sletten, et al., 2013; Papadelis et al., 2007). It is perhaps not surprising then, that there is a focus on the eyes when people are asked to evaluate someone's fatigue/tiredness from a facial photograph (Nguyen, et al., 2009). It seems indications of these eye-related dynamic cues can be captured in a picture as well, with half-closed eyes making a face look more tired, and swollen-looking eyes increasing the appearance of tiredness and sadness (Knoll, et al., 2008). But we do not know whether this is what the eyes of someone who is sleep deprived look like, nor whether there are other features than eye closure that make a face look tired. One suggestion might be dark circles under the eyes, which are casually referred to in the scientific literature as "no doubt" being "worsened by general fatigue, especially lack of sleep" (Freitag & Cestari, 2007, p.212; Roh & Chung, 2009), but no previous study seems to actually have measured the validity of this statement.

If appearance is affected by sleep loss it is reasonable to assume that others would treat sleep-deprived people differently than those who have slept. If a sleep-deprived person becomes less attractive (missing out on their beauty sleep), others may find them less socially desirable due to the misconceptions we have about attractive people being more sociable and competent. In addition, looking unhealthy might make others even more aversive, and appearing tired could actually signal a worse mood, less sociability, and impaired cognitive abilities. In other words, a sleep-deprived person might look like someone we would not want around – personally or professionally.

Considering the prevalence of short sleep, especially in the working population (Knutson, et al., 2010), any incentive to prioritize sleep would be beneficial. Perhaps knowing that one's appearance is affected would be a contributing factor to the individual, and knowing it might affect how others perceive your employees would influence employers' and managers' viewpoints. Furthermore, if there are certain tell-tale visual cues as to who has slept and who has not, who is tired and who is not, it could help improve fatigue-detection systems both in traffic situations and the workplace (Dawson, Searle, & Paterson, 2014).

Note: a few articles on sleep loss and appearance have been published after Study I and Study II of this thesis. Since those articles refer to these studies they will be included in the discussion rather than the introduction.
Aims

The general aims of this thesis were to investigate the effects of sleep loss on appearance, factors contributing to these effects, and possible social consequences thereof. Specifically, the following questions were considered.

1) Does sleep loss make people look more tired and more sleepy? And do sleep loss and looking tired make people look less healthy? (Studies I, II, III, & IV)

2) What is it about a face that makes it look tired and is this affected by sleep deprivation? (Study II)

3) Does sleep loss affect attractiveness, i.e. is there truth to the concept of beauty sleep? If yes, is this due to sleep-deprived people looking less healthy and more tired? (Studies I, III, & IV)

4) Does a sleep-deprived appearance influence others' assumptions about, and reactions toward, that person? If so, is this because sleep loss makes people look less attractive, less healthy, more tired, and more sleepy? (Studies III & IV)
Methods

To assess the effects of sleep loss on appearance, the first step was to experimentally induce sleep loss, the second was to take facial photographs, and the third was to have people evaluate the faces in those photographs.

Sleep loss

In order to compare sleep loss to normal sleep, all participants were photographed on two occasions at least one week apart; once after normal sleep and once after sleep loss. The studies in this thesis contain two different sleep manipulations: total sleep deprivation and sleep restriction.

Participants

Participants were screened for physical and mental health, as well as sleep problems. Based on a self-report questionnaire, anyone with health concerns or suspected sleep disorders were excluded. Possible participants were also excluded if they had a sleep need shorter or longer than 7-9 hours per night, if they were heavy coffee drinkers (as they were not allowed to drink coffee during the waking nights), nicotine users, psychology students, non-Swedish speakers (due to cognitive tests performed after the photographs were taken, the results of which are not reported here), or younger than 18 years or older than 45. Photographs of one set of participants were used for Studies I and II and photographs of another set were used for Studies III and IV. The total amount of participants was 48, having excluded 86 for the reasons above.

Total sleep deprivation

For Study I and Study II, participants were photographed after one night of total sleep deprivation following one night of sleep restriction to 5 hours. Participants slept in their homes during the sleep-restriction night and sent a text message upon bedtime and wake-up to confirm their sleep times. On the following evening they came into the lab at 22.00 where they stayed awake in small groups of 3-6 people, accompanied by a lab member. They accumulated on average 31 hours of total sleep deprivation, on top of only sleeping...
5 hours the night before. They were also photographed after one night of normal sleep, i.e. after having been awake around 7 hours following two nights of 7-8 hours of sleep.

Just prior to the photographs being taken, participants rated their own sleepiness on the Karolinska Sleepiness Scale, ranging from 1 - extremely alert, to 9 - extremely sleepy, fighting sleep (Akerstedt & Gillberg, 1990). The mean value in the sleep-deprivation condition was 7.87, with a standard deviation of 1.42, and in the normal sleep condition the mean was 4.83, standard deviation 1.34. A paired t-test confirms that participants were more sleepy when they had not slept (t(22)=7.26, 95%CI[2.17,3.91], p<0.001). Looking at the individual ratings, all participants but two chose a higher number on the sleepiness scale when they were sleep deprived.

Sleep restriction
For Study III and Study IV, participants were instead photographed after two nights of sleep restriction where they were not allowed to spend more than 4 hours in bed per night. They could choose their bedtime between 00.00 and 02.00 and wake up between 04.00 and 06.00. For the normal sleep condition, they were instructed to sleep 8 hours per night for two nights, with bed times from 22.00-00.00 to 06.00-08.00. To confirm adherence to the sleep protocol, participants wore actigraphs (Camntech, AW4, Cambridge, Great Britain); a watch-like device worn on the non-dominant arm that measures movement and provides a good estimate of sleep times (Sadeh, 2011). They also sent text messages upon turning the lights out and waking up, and filled out a sleep diary the four mornings of the study. On both occasions they came into the lab in the early afternoon, between 13.00 and 15.30. Each participant arrived at the same time for both sessions.

As with the total sleep-deprivation paradigm, there was a difference in participants' ratings on the Karolinska Sleepiness Scale between the two conditions. The mean value on the scale for sleep restriction was 6.00, with a standard deviation of 1.98, and for normal sleep the mean was 3.12, and the standard deviation 0.97 (t(24)=7.49, 95%CI[2.09,3.67], p<0.01). All participants but three rated themselves as more sleepy when their sleep had been restricted.

Photographs
Facial photographs were taken from the front with participants looking straight into the camera. At each photo shoot, the photographer made sure to
get a minimum of 5-6 "good" photos, i.e. with eyes open and a neutral facial expression. Two photographs of each participant, one from each condition, were later chosen by colleagues with no knowledge of the purpose of the study nor of the difference in sleep between the conditions. They were instructed to choose "the most representative photo" from each shoot, in other words the photo which most resembled the other 4-5 photos taken during the same shoot.

Studies I & II

Colour photographs were taken with a Nikon D80, using a focal length between 44 and 58mm, depending on the head size of the participant, and a resolution of 3872x2592 pixels. The white balance was set to 4200K. The background was a solid medium grey sheet and the room was well lit with 5 stationary lamps surrounding the participant. The participants wore no make up and had their hair loose and away from their face. They were instructed to sit with a straight back and look straight into the camera with a neutral, relaxed facial expression. Photographs were taken between 14.00 and 15.00 on both occasions for all participants. Subjects were provided with a dark grey t-shirt which they wore on both occasions.

Studies III & IV

Colour photographs were taken with a Nikon D90 with a 55mm lens and a resolution of 4288x2848 pixels. The white balance was set to 5880K. The background was a white fabric photo background and lighting was provided by two Elinchrom softbox flashes set to an output of 1.2 (approximately 14 watt-seconds). The participants wore the same dark grey t-shirt on both occasions. They had their hair pulled back from their face and up if long. They wore no make up and no extensive jewellery. They were instructed to sit comfortably, look straight into the camera, and relax their face. Photographs were taken between 13.30 and 16.00, but always at the same time for the same participant in both conditions.

Ratings

The ratings were set up in blocks, so that all photographs were rated on one aspect (e.g. attractiveness) before all photographs were rated on another aspect (e.g. health).
Raters

Ratings were made by people from universities and the general public in Stockholm, Sweden, with no prior knowledge about the purpose or manipulations of the studies. The only exclusion criteria were an age younger than 18 years or older than 65 years, lacking Swedish fluency, and having studied psychology (in order to minimise demand characteristics). The total number of raters across the four studies was 287.

Studies I & II

The photographs were presented one by one in a pre-set order. They had been randomized into two groups (the same face only appearing once in either group) and the order within each group had also been randomly set. In the middle of every block, when the first group of photographs had been rated, there was a working-memory task in order to prevent memorization of the faces and previous ratings before the second group of photographs was shown. The photographs were displayed in PowerPoint at a set speed of 5 seconds/photograph, and ratings were indicated in a provided booklet. Ratings were made on 100mm visual analogue scales, due to them requiring very little studying and allowing for fine discriminations (Freyd, 1923; Maxwell, 1978).

In study I, ratings were collected for multiple raters at the same time, displaying the PowerPoint presentation on a large screen. In study II, ratings were collected for one rater at a time, with the PowerPoint being displayed on a 12-inch laptop computer screen.

Studies III & IV

For the later studies, the task was programmed in E-prime and responses were entered directly into the program. Ratings were made on 7-point scales to more closely resemble other face-rating studies (e.g. Jones, et al., 2001; Perrett, May, & Yoshikawa, 1994; Willis & Todorov, 2006). The photographs were viewed one by one, but this time they were shown in a pseudo-randomized order so that the same participant was never displayed directly after him-/herself. All ratings were made by one rater at a time, watching the photographs on a 17-inch laptop computer screen. Each photograph was displayed for a maximum of 5 seconds; the time was self-paced depending on how quickly a response was recorded. The working memory tasks were performed between each block instead of within.

In study III the blocks were in a set order and the same photograph could be shown more than once within each block due to a programming error. How-
ever, no photograph was shown more than twice in the same block. In study IV the first three blocks (assessing the main dependent variables) were in a randomised order and the last two blocks (assessing the presumed mediating variables) were in a set order. There was no replacement of photographs in study IV so each picture was only shown once in every block.

Analyses

Analyses were performed using mixed linear regression, with cross-classified random effects for faces and raters where appropriate. Mixed linear models are usually applied to hierarchical data, with different levels of analysis combined into the same model. However, cross-classification makes it possible to take several factors on the same level into account (e.g. Zaccarin & Rivellini, 2002). In this case, since every rater rated all faces and every face was rated by all raters, the two variables are on the same level rather than one being nested within the other. This made it possible (and preferable) to allow for random intercepts for each face as well as for each rater, a procedure which reduced error variance due to differences in ratings between raters and between faces, respectively.
Summary of studies

Table 1. Summary of studies.

<table>
<thead>
<tr>
<th>Study</th>
<th>Title</th>
<th>N (photographed participants)</th>
<th>N (raters)</th>
<th>Sleep manipulation</th>
<th>Ratings</th>
<th>Scale</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Beauty Sleep: Experimental study on the perceived health and attractiveness of sleep deprived people</td>
<td>23</td>
<td>65</td>
<td>31 hours of total sleep deprivation following a night of sleep restriction to 5 hours</td>
<td>Attractiveness, Health, Tiredness</td>
<td>10cm visual analogue scale</td>
</tr>
<tr>
<td>II</td>
<td>Cues of Fatigue: Effects of sleep deprivation on facial appearance</td>
<td>10 (from study I)</td>
<td>40</td>
<td>31 hours of total sleep deprivation following a night of sleep restriction to 5 hours</td>
<td>Tiredness, Hanging eyelids, Red eyes, Swollen eyes, Dark circles under the eyes, Pale skin, Wrinkles/fine lines, Droopy corners of the mouth, Glazed eyes, Rash/eczema, Sadness</td>
<td>10cm visual analogue scale</td>
</tr>
<tr>
<td>III</td>
<td>Effects of restricted sleep on facial appearance and social appeal</td>
<td>25</td>
<td>122</td>
<td>Two nights of sleep restriction to 4h/night</td>
<td>Willingness to spend time, Trustworthiness, Attractiveness, Health, Sleepiness</td>
<td>7-point scale</td>
</tr>
<tr>
<td>IV</td>
<td>Sleep in and get the job: The relationship between sleep restriction and perceived employability and leadership ability</td>
<td>24 (from study III)</td>
<td>61</td>
<td>Two nights of sleep restriction to 4h/night</td>
<td>Employability, Leadership ability, Trustworthiness, Attractiveness, Tiredness</td>
<td>7-point scale</td>
</tr>
</tbody>
</table>

Study I


The focus of study I was whether sleep deprivation affects appearance in terms of other-rated tiredness, health, and attractiveness. A second focus was to look into the relationship between appearing tired, healthy, and attractive.
Method

Twenty-three participants (mean age 22.7±3.3 years, 11 women) were photographed after sleep deprivation and after normal sleep. Sixty-five raters (mean age 30 years, 40 women) evaluated the faces in the 46 photographs on attractiveness (very unattractive - very attractive), health (very sick - very healthy), and tiredness (not at all tired - very tired), in that order.

Results

Sleep deprivation led to participants' looking more tired, less healthy, and slightly less attractive compared to when they had slept. On the 100mm visual analogue scale, there was a difference of 8.3mm in the ratings of tiredness, 4.2mm in the ratings of health, and 1.6mm in the ratings of attractiveness between the two conditions.

When people looked more tired they also looked less attractive and less healthy (see Figure 1). Confirming previous studies, attractiveness was related to looking healthy. Tiredness seemed to partially mediate the effects of sleep deprivation on both health and attractiveness, decreasing the differences in ratings between the two conditions to 1.8mm and 0.6mm, respectively, when kept constant. Health also seemed to mediate the effects of sleep deprivation on attractiveness, decreasing the difference to 0.6mm.

Figure 1. Relationship between ratings of tiredness and (a) attractiveness, and (b) health on 100mm scales. Fitted regression lines are based on the mixed model allowing for random intercepts between raters. Dots are raw data, with each dot representing one rating of one face.
Conclusion

One night of total sleep deprivation following a night of sleep restriction has a noticeable effect on people's appearance. Mainly, sleep-deprived people look more tired, less healthy, and somewhat less attractive.

Study II


In study II, the focus was to evaluate certain facial features commonly assumed to be related to sleep loss and tiredness in order to see whether they actually are.

Method

Pictures of 5 women and 5 men were randomly chosen from Study I (after excluding 3 participants with very low variation in other-rated tiredness), resulting in a total of 20 photographs. A smaller sample was chosen in order to limit the fatiguing effects of time-on-task for the raters. Forty raters (mean age 25±5 years, 20 women) evaluated the faces on fatigue/tiredness (not at all fatigued - very fatigued), dark circles under the eyes (no dark circles - very dark circles), red eyes (not at all red - very red), glazed eyes (not at all glazed - very glazed), hanging eyelids (not at all hanging - very hanging), swollen eyelids (not at all swollen - very swollen), pale skin (not at all pale - very pale), wrinkles/fine lines (no wrinkles/fine lines - a lot of wrinkles/fine lines), rash/eczema (no rash/eczema at all - a lot of rash/eczema), corners of the mouth pointing down (not at all - very much), tense lips (not at all tense - very tense), and sadness (not at all sad - very sad). The ratings were always done in the above order.

These facial features were chosen based on answers from 50 undergraduate students and 10 sleep researchers from different countries to the question "what do you associate with looking fatigued/tired?". A total of 53 features were suggested and rated by another group of 61 students as well as the same 10 sleep researchers on how likely they would be to appear on a fatigued/tired person. After removing features concerning movement/dynamic behaviours (e.g. "yawning") and being unkempt (e.g. "messy hair"), six emerged as clear favourites (hanging eyelids, red eyes, swollen eyes, glazed eyes, dark circles under the eyes, and pale skin) and another three
kles/fine lines, rash/eczema, and corners of the mouth pointing down) were added to balance out the focus on the eyes. Assuming both glazed eyes and corners of the mouth pointing down would be indicative of a sad face, sadness was added to the list of aspects rated. The feature “tense lips” was intended to serve as a control.

Results
When sleep deprived, faces were rated as having more hanging eyelids, redder eyes, more swollen eyes, darker circles around the eyes, paler skin, more wrinkles/fine lines, and more droopy corners of the mouth compared to when they were not sleep deprived. Differences in ratings on the 100mm scale ranged from 2.9mm (paler skin) to 14.8mm (hanging eyelids). Sleep-deprived faces also looked more tired (8.5mm difference) and more sad (10.8mm difference).

Looking more tired was related to the same features as sleep deprivation, as well as glazed eyes and sadness (see Figure 2a-h).

Rash/eczema or tense lips were not related to sleep deprivation (differences in ratings were 0.8mm and 0.5mm, respectively) nor to looking tired (see Figure 2i-j)
Figure 2. Relationship between other-rated tiredness and (a) hanging eyelids, (b) dark circles under the eyes, (c) red eyes, (d) glazed eyes, (e) swollen eyes, (f) wrinkles/fine lines around the eyes, (g) pale skin, (h) droopy corners of the mouth, (i) rash/eczema, and (j) tense mouth on 10cm scales. Fitted regression lines are based on the mixed model allowing for random intercepts between raters. Dots are raw data, with each dot representing one rating of one face.

The relationships between sleep deprivation and facial features held true for both men and women, with the exception of pale skin and tense lips which were approaching significance for men but not for women.

Conclusion

There are facial features which are affected by sleep deprivation and these same facial features are also related to looking more tired. The biggest culprits are hanging eyelids, swollen eyes, and droopy corners of the mouth. Sleep-deprived and tired-looking people also appear more sad.

Study III

Sundelin, T., Lekander, M., & Axelsson, J. (Submitted). The effects of restricted sleep on facial appearance and social appeal.
The main focus of study III was how others perceive a sleep-restricted person in terms of sociability, and whether they would be less inclined to spend time with sleepy-looking people. A second focus was to see whether less severe sleep loss than staying up a whole night would result in a more sleepy, less attractive, and less healthy appearance. Sleepiness was rated instead of tiredness in order to see whether this construct would also be visible in someone's face. Considering that attractiveness and trustworthiness are both on the valence-dimension of facial judgements (Todorov, Said, Engell, & Oosterhof, 2008), trustworthiness was added as a potential mediating factor.

Method

Twenty-five participants (mean age 23.9±5.9 years, 14 women) were photographed after sleep restriction and after normal sleep. The photographs were evaluated by 122 raters (mean age 30.8±13.3 years, 65 women, one of undisclosed gender) on how willing they were to socialise with the participant (not at all - very much), the participant's trustworthiness (very untrustworthy - very trustworthy), attractiveness (very unattractive - very attractive), health (very poor - very good), and sleepiness (very sleepy - extremely alert). The rating blocks were always presented in the above order.

Results

Raters were less willing to spend time with participants when the participants had not gotten enough sleep. The average difference between the two conditions was 0.15 steps on the 7-point scale. After sleep-restriction, participants were also rated as less attractive (-0.09 steps on the 7-point scale), less healthy (-0.11 steps), and more sleepy (0.25 steps). There was no difference in trustworthiness between the two conditions.

Raters were more willing to socialise with participants when they looked less sleepy (see Figure 3a). They were also more willing to socialize when participants looked more attractive, more healthy, and more trustworthy. However, none of these factors seemed to fully mediate the effect of sleep restriction on willingness to socialise.

Like tiredness in Study I, looking sleepy was related to looking less healthy and less attractive (see Figure 3b-c)
Figure 3. Relationship between sleepiness and (a) willingness to socialize, (b) health, and (c) attractiveness on 7-point scales. Fitted regression lines are based on the mixed model allowing for random intercepts between raters. Dots are raw data, with each dot representing one rating of one face. Jitter has been applied to better show the distribution of ratings.

Conclusion
Others are slightly less willing to spend time with people who are sleep-restricted, and this response is not fully explained by a decrease in attractiveness or health. Sleep-restriction to 4 hours per night for two nights is enough to negatively affect one's appearance regarding sleepiness, health, and attractiveness.
Study IV

Sundelin, T., Garke, M., Svensson, I., & Axelsson, J. (Submitted) Sleep in and get the job: The effect of sleep restriction on perceived employability and leadership ability.

The focus of study IV was to see whether a sleep-restricted appearance would affect how employable a person seems and whether someone who has not slept well is perceived as a poorer leader. The effect of looking tired on these two perceptions was also investigated, as well as the possible mediating factors attractiveness and trustworthiness.

Method

Photographs of 24 of the 25 participants from Study III were used for this study (mean age 22.9±3.3 years, 13 women). One participant was excluded due to programming difficulties; needing an even number (24) for randomization of the order in which photographs were shown. The excluded participant was chosen on account of being female (thus slightly evening out the gender difference) and 10 years older than the second oldest participant. The 48 photographs were evaluated by 61 raters (mean age 25.9±6.2 years, 30 women, 30 men, one of unspecified gender) on how likely they would be to hire the person in the photo (very unlikely - very likely), their leadership ability (very poor - very good), trustworthiness (very untrustworthy - very trustworthy), intelligence (very unintelligent - very intelligent), attractiveness (very unattractive - very attractive), and tiredness (not at all tired - very tired). The first four blocks were presented in a random order whereas the last two were always presented last, in the above order.

Ratings of intelligence were included as part of a separate study (Thalamus et al., in prep) and have thus not been analysed here.

Results

When sleep-restricted, participants were rated as less likely to be hired (on average -0.16 steps on the 7-point scale), poorer leaders (on average -0.19 steps), less trustworthy (-0.12 steps), less attractive (-0.14 steps), and more tired (0.14 steps). Tired-looking people were also considered less employable and worse leaders (see Figure 4). The effect of sleep restriction on employability disappeared when adding the ratings of attractiveness, trustworthiness, and tiredness to the analysis, suggesting that these are mediating factors. On the other hand, the relationship between sleep restriction and perceived leadership ability was only slightly diminished, indicating that it is
not fully explained by sleep-deprived participants' looking less attractive, less trustworthy, and more tired.

Figure 4. The relationship between other-rated tiredness and (a) employability, and (b) leadership ability on 7-point scales. Fitted regression lines are based on the mixed model allowing for random intercepts between raters. Dots are raw data, with each dot representing one rating of one face. Jitter has been applied to better show the distribution of ratings.

Conclusion

Two nights of restricted sleep changes how others perceive a person's face, evaluating that person as less employable and a poorer leader. Looking less employable after sleep restriction is likely due to an increased appearance of tiredness, decreased attractiveness, and decreased trustworthiness, whereas being perceived as a poorer leader is not fully explained by these factors.
General discussion

Aims revisited

The general aims of this thesis were to investigate the effects of sleep loss on appearance, factors contributing to these effects, and possible social consequences thereof. This was done through four studies, all of which support the idea that sleep loss has a negative impact on one's appearance and suggest that this may affect how others treat a sleep-deprived person. The specific questions toward these aims are addressed and discussed below.

1) Does sleep loss make people look more tired and more sleepy? And do sleep loss and looking tired make people look less healthy?

When it comes to looks, several factors are involved in how others perceive us, and sleep history seems to be one of them. All four studies showed that sleep loss, whether from total sleep deprivation or two nights of sleep restriction, affects one's facial appearance. Studies I, II, and IV showed that less sleep makes people look more tired and Study III showed the same for sleepiness. This was the case for 35 of the 47 faces rated for tiredness, and for 20 of the 25 faces rated for sleepiness. Photographs of people acting sleepy, as in the study by Fujimura and Suzuki (2010), may thus be indicative of the real thing.

Studies I and III also assessed how healthy participants looked after not sleeping properly, finding that they looked less healthy and that a less healthy appearance was related to a more tired and sleepy one. Corroborating these findings, a recent study on patients with sleep apnoea showed that after at least two months of treatment they were considered more healthy-looking than their untreated, sleep-deprived selves (Chervin et al., 2013). One possible mechanism for this is the effect sleep loss has on skin quality and function. During sleep, the skin is subject to a vast increase in blood flow, which regulates temperature but has also been suggested to redistribute immune cells to the periphery (Van Someren, 2006). During sleep deprivation, this blood flow to the skin is hampered (Kräuchi & Wirz-Justice, 2001; Van Someren, 2006), possibly contributing to decreased skin health. When aggravating the skin by tape stripping, self-reported poor-quality sleepers have a slower skin recovery than self-reported good-quality sleepers.
(Oyetakin-White et al., 2015). Poor sleepers are also generally less satisfied with the appearance of their skin (Gupta, Gupta, & Knapp, 2014). Whether skin function and blood profusion are related to the less healthy appearance that is a result of sleep loss remains to be investigated.

2) What is it about a face that makes it look tired and is this affected by sleep deprivation?

Study II showed that many of the features colloquially (and professionally) assumed to make someone look tired are indeed related to looking tired. Corroborating previous studies with human raters (Nguyen, et al., 2009; Wierwille & Ellsworth, 1994), as well as automated ocular measures (e.g. Anderson, et al., 2013), these features particularly include those related to the eyes, such as hanging eyelids and swollen eyes. Apart from glazed eyes, which indicates tiredness but not sleep deprivation, the features of a tired face seem to be the same as those of a sleep deprived face. In other words, not sleeping affects facial cues that are commonly assumed to indicate tiredness, like dark circles under the eyes and paleness.

The prevalence of sleep-loss related dark circles was questioned by Oyetakin-White et al. in a recent study (2015). They did not find any difference in under-eye dark circles between 30 self-reported poor sleepers and 30 self-reported good sleepers, based on one staff members’ evaluation of standardized photographs. However, the effects of hereditary factors such as eye-lid fat, as well as sun-damage, allergies, and edema (which could be worse in the mornings and after eating salt) (Freitag & Cestari, 2007; Goldberg, McCann, Fiaschetti, & Ben Simon, 2005) are likely much bigger than those of sleep loss. In other words, the likelihood of finding an impact of sleeping habits on dark circles in a between-subjects design is quite small, unless the sample size is indicative of substantial power.

The paleness of participants’ faces may further influence ratings of health, since less red skin makes for a less healthy look (Stephen, Coetzee, et al., 2009). However, the study on the appearance of patients with sleep apnoea showed decreased redness of the cheeks and underneath the eyes after successful treatment (Chervin, et al., 2013), indicating that how the colouration is distributed needs to be taken into account in future studies.

Due to the stimuli set being rather small, the separate analyses for men and women should be interpreted with caution. Since gender effects were not the focus of this thesis, no further gender-based interactions have been assessed. Nevertheless, it would be interesting to investigate whether sleep loss affects men’s and women’s appearances differently.
3) Does sleep loss affect attractiveness, i.e. is there truth to the concept of beauty sleep? If yes, is this due to sleep-deprived people looking less healthy and more tired?

The results of Studies I, II, and IV indicate that there is some truth to the concept of beauty sleep. Whether you have experienced acute sleep deprivation or a less severe sleep restriction, odds are that you will be perceived as less physically attractive compared to your well-rested self. This effect may not be very large, but seems robust across several studies and a majority of individuals (only 14 out of the 48 faces were rated as equally or more attractive after sleep loss). This finding has also been corroborated by two studies on natural sleep loss, one showing that people suffering from sleep apnoea were perceived as more attractive after treatment (Chervin, et al., 2013), providing support for beauty sleep from a clinical context, and the other reporting that chronic poor sleepers were less satisfied with their own appearance compared to good sleepers (Oyetakin-White, et al., 2015).

Whether the effects of sleep loss on attractiveness are solely due to the decrease in health or tiredness is not entirely clear. In Study I, both health and tiredness separately mediated the effects of sleep deprivation on attractiveness. This was true for Study III as well, except a sleepy appearance was a more prominent factor than an unhealthy appearance. However, in Study IV, keeping tiredness constant barely affected the impact of sleep restriction on attractiveness at all (only reducing the effect from -0.15 to -0.14 steps on the 7-point scale). Another factor that may be contributing is the sleep-deprived individuals' looking more sad, since a sad appearance is considered slightly less attractive than a happy or neutral one, at least for women (Morrison, Morris, & Bard, 2013; Mueser, Grau, Sussman, & Rosen, 1984).

As mentioned previously, healthy-looking skin is generally considered more attractive (Jones, Little, Burt, et al., 2004), and this may be one contributing mechanism to the effect of sleep loss on attractiveness. There have been no studies looking at the relationship between attractiveness and markers of tiredness or sleepiness, e.g. droopy eyelids and dark circles under the eyes, although many plastic surgeons refer to these as cosmetic concerns (Freitag & Cestari, 2007; Goldberg, et al., 2005; Gulyas, 2006; Roh & Chung, 2009).

4) Does a sleep-deprived appearance influence others' assumptions about, and reactions toward, that person? If so, is this because sleep loss makes people look less attractive, less healthy, more tired, and more sleepy?
In Study III, the ratings of facial photographs show that when someone looks sleepy, based on sleep restriction or otherwise, people indicate being less willing to spend time with that person. Again, the effects of sleep restriction are small, but they are not fully explained by the increase in perceived sleepiness, attractiveness, or health. Going from a very sleepy appearance to a very alert one, however, is associated with more than one whole increment on a 7-point scale of willingness to socialize.

Based solely on facial appearance, sleep-restricted people are also considered slightly less employable and poorer leaders, as shown in Study IV. Attractiveness and tiredness both play their parts in this, with a less attractive, more tired person also being perceived as less employable and a poorer leader. For employability, the decreased attractiveness and increased tiredness after sleep restriction seem to be the driving factors but for leadership they are not the only mediators.

Another factor which has been implicated in choosing leaders is how healthy they look, both in terms of their face (Spisak, Blaker, Lefevre, Moore, & Krebbers, 2014) and how they move (Kramer, et al., 2010). Although the raters in study IV did not evaluate the health of participants' faces, the same faces were shown to the raters in Study III, who did. Therefore, to see whether perceived health could explain the remaining variance and thus mediate the effect of sleep loss on perceived leadership skill, another mixed linear regression analysis was carried out, including the health scores the faces had received in Study III. This decreased the effect of sleep restriction on perceived leadership ability from 0.19 steps on the scale to 0.08 (95% CI[-0.16,0.00], p=0.065), indicating that it is a substantial mediating factor.

The relationship between sleep loss and trustworthiness was not a main focus of this thesis but trustworthiness was added as a possible mediator for willingness to socialize, employability, and leadership ability. The discrepant results between Studies III and IV on this factor were believed to be due to the context in which the ratings were made (DeBruine, 2005; Little, Roberts, Jones, & Debruine, 2012; Todorov & Porter, 2014); one in relation to a personal social setting and the other focusing on the professional/public sphere. In order to test this hypothesis, a separate analysis was performed on the trustworthiness responses from the raters who rated trustworthiness first in Study IV, i.e. those who could not have been primed by the other, work-related, questions. However, the difference between the effects of sleep restriction on trustworthiness for these raters ($b=-0.16$, 95% CI [-0.29,-0.02], p=0.029) compared to the other raters ($b=-0.11$, 95% CI [-0.20,-0.02], p=0.022) was not in the direction expected. Possibly, it was the setting of Study III, with the fixed order of sociability rated before trustworthiness,
which influenced the trustworthiness ratings rather than the setting of Study IV. When the ratings of both studies were analysed together, with a total of 162 raters, the effect of sleep restriction on trustworthiness was small ($b=-0.08$), but with a more narrow 95% confidence interval [-0.13, -0.03] and a $p$-value of 0.004. It thus seems possible that sleep restriction has a minor effect on trustworthiness, but this should be tested further and with more specific information regarding what is meant by the concept. It would also be interesting to study the actual trust one places in a sleep-deprived person, for example through trust-based economic games.

As with the other results, there are factors which have a bigger impact on assumptions about someone than their sleep history or facial tiredness. This is particularly true for perceptions of leadership and employability. For example, perceived competence and emotional disposition have a sizable effect on leader choices (Olivola & Todorov, 2010a), although the appearance of these might of course be affected by not sleeping as well! While physical appearance definitely plays a part in whom we find attractive and want to be around (see e.g. Rhodes, 2006), having similar attitudes is by far the biggest factor influencing liking and mate choice (Bleske-Rechek, Remiker, & Baker, 2009; Nagoshi, Johnson, & Honbo, 1992). The effects of sleep loss, inasmuch as they affect appearance, may thus not be among the main reasons for avoiding spending time with someone or choosing not to employ a person. But within the same individual, or between two people who are very much alike, sleep history could make a difference in how others perceive them and behave towards them. Coupled with the possibility that sleep-deprived people actually behave differently, the two may interact and enhance the negative response.

As described earlier, attractive people are often assumed to be more intelligent, sociable, and competent, but this is not necessarily reflected in reality (Feingold, 1992). As many as 75% of people believe that it is possible to know at least some of a person's true personality traits from just looking at their face (Hassin & Trope, 2000). Studies investigating the accuracy of this claim have focused on traits ranging from intelligence, competence, and sexual orientation, to occupation, dominance, and locus of control; and the belief is generally quite inaccurate (Olivola & Todorov, 2010b). One reason might be that these are traits which are unlikely to change overnight. Sleep loss, however, has been shown to actually change people's mental capacity (Killgore, 2010), impulse control (Anderson & Platten, 2011), and possibly even empathy (Gordon & Chen, 2013; Guadagni, et al., 2014). The extent to which we are able to tell that someone is sleep deprived, and perceive them as more tired or sleepy, might generate more accurate inferences about that person than other facial cues would. These inferences would be about states
rather than traits and, as such, be vulnerable to the fundamental attribution error (attributing behaviours to personality rather than situational factors) (Ross, 1977), but still comparatively accurate at that moment. That is, thinking that a sleep-deprived person is a poorer employee and a worse leader could actually reflect the fact that sleep-deprived people have impaired cognitive functions (e.g. Killgore, 2010; Walker, 2008). In turn, a reduced willingness to spend time with someone who has not slept could actually be an appropriate response. Would you want to be around someone with increased emotional reactivity (Yoo, et al., 2007) and reduced feelings of optimism and sociability (Haack & Mullington, 2005)? If that person is also worse at understanding your facial expressions (Cote, Mondloch, Sergeeva, Taylor, & Semplonius, 2014; Maccari et al., 2014; van der Helm, et al., 2010), less empathic (Guadagni, et al., 2014), worse at solving conflicts (Gordon & Chen, 2013), and more aggressive than usual (Kahn-Greene, et al., 2006; Kamphuis, Meerlo, Koolhaas, & Lancel, 2012), it might give you even more of a reason to stay away. Perhaps someone with sleep loss just wants to be left alone in order to get some rest, hence their feeling less sociable and acting less sociably. Whether or not these are the reasons behind our evaluations of tired-looking people remains to be investigated, for example by asking how likely someone is to display certain behaviours given the appearance of their face.

It is alluring to speculate about the reasons behind being able to classify people based on tiredness or sleep loss — reasons such as those mentioned above — but it is at least equally possible that this ability is secondary to the physiological effects of not sleeping. For example, hanging eyelids may simply be due to the struggle of keeping one’s eyes open and if someone is falling asleep we can assume they will not be very social or focused. Moreover, looking tired is related to looking sick and we seem to be able to tell just by watching people walk (Sundelin et al., 2015) or smelling them (Olsson, et al., 2014) that they have an activated immune response. Perhaps then, the basis of the negative evaluations of people with sleep loss is one of sickness avoidance. Regardless, the inferences drawn from a tired appearance are robust and detrimental, suggesting that they may have been beneficial in the past.

Strengths and limitations

There are a few obvious limitations to the generalizability of these findings. First and foremost, the faces in the photographs all belonged to healthy individuals between 18 and 47, a vast majority of which were Caucasian. Whether these same effects can be found in faces of people of different ages,
different ethnicities, and different health profiles has not been addressed. One might argue that considering the proposed universality of the facial expressions of certain emotions (e.g. Ekman, et al., 1987), tiredness or sleepiness may be equally informative and universal. For example, someone who looks tired may be less healthy and have a lower reproductive value, two factors which would have been evolutionarily advantageous to be able to recognize.

As with all sleep-deprivation studies, the participants who chose to take part are more likely to be less aversely affected by not sleeping. Someone who reacts very strongly to sleep loss would not be expected to volunteer for such an experiment. It is therefore possible that the effects found in this thesis would be more pronounced in the general population, assuming there is a relationship between how well someone copes with sleep loss and how they appear after not sleeping.

Another limitation, regarding the ecological validity, is that the setting for the photographs was not particularly natural. Participants were seated in a rather sterile environment and told to look straight into the camera with a relaxed face. This is not generally what we look like when we are around other people, nor is it usually what we look like in photographs (except maybe for those used in passports). However, photographs taken in natural settings are harder to standardize and would therefore have compromised the confidence that the results are due to sleep loss rather than other factors. In this case, because the photographs were taken with such strict standardization, that risk is rather small. It would be interesting to see whether natural settings would increase or decrease the ability of others to perceive a person's sleep history.

Speaking of natural settings, we usually have multisensory dynamic interactions with people rather than stare at an image frozen in time. Of course, we also communicate via social media where a photograph (or several) is one's face to the world, but these photographs can be chosen with care, manipulated and edited. A more "true" effect of sleep loss on others' impressions of someone might therefore be obtained through dynamic behavioural observations rather than from static images. As previous studies have suggested that we perceive drowsiness based on eye-lid closure (Wierwille & Ellsworth, 1994), behaviours such as blinking slowly, yawning, and inappropriate prosody (Harrison & Horne, 1997) may provide more reliable cues to sleep loss than facial appearance alone. This also relates to the relatively small effect sizes of the current studies. On the one hand, behaviours, as well as wearing make-up and drinking coffee, may occlude the appearance of sleepiness or tiredness; but on the other, they may exacerbate the effects through slouch-
ing or other drowsiness-related body movements, on top of the facial and vocal cues mentioned above.

On the topic of effect sizes, they may be small (ranging from 1.6-14.8mm on a 100mm scale and 0.09-0.25 steps on a 7-point scale) but seem consistent across two different sleep-loss protocols and four different collections of ratings with a total of over 200 raters. Furthermore, since the first two studies were published, the concept of beauty sleep has been corroborated by two studies focusing on chronic sleep loss (Chervin, et al., 2013; Oyetakin-White, et al., 2015), both regarding others' perceptions and one's own. Although one night of sleep deprivation or two nights of sleep restriction have small effects on appearance, looking tired or sleepy seems to be fairly strongly related to how one is perceived. Also, the sum of the potential effects may be quite big considering the vast prevalence of poor sleep (Ohayon, 2002).

Future directions

In addition to studies addressing such things as age and ethnicity, and possibly natural settings and dynamic images, the main future directions should include steps toward elucidating mechanisms as well as investigating real-life interactions.

Mechanisms

Are skin redness and skin health the driving forces behind the effects of sleep loss on appearance or are there other factors? Looking at the pigmentation and condition of the skin through objective measures and relating these to subjective ratings is one way of studying these potential mechanisms. Two studies have looked at skin barrier function – how quickly the skin recovers from tape-stripping – after experimental sleep deprivation (Altemus, et al., 2001) and in chronic bad sleepers (Oyetakin-White, et al., 2015), finding that the recovery of this function is slower after sleep loss. Sleep apnoea patients, on the other hand, have decreased redness of the cheeks after treatment, along with decreased redness underneath the eyes (Chervin, et al., 2013). How skin colouration differs after sleep and sleep loss in non-clinical samples has yet to be investigated, but might provide a clue to the underlying physiological mechanisms of a sleep-deprived face.

Considering the relatively large effect of features related to the eyes in indicating sleep history, it would be interesting to look at the relationship between e.g. droopy eyelids, swollen eyes, and dark circles under the eyes and
the appearance of health and attractiveness. We also do not quite know what the reasons are for these changes after sleep loss. Why do we become more pale, have more sad-looking mouths, and fine wrinkles around the eyes?

There may certainly be other features of a sleep-deprived face that function as cues to a person’s sleep history than those investigated in Study II. Letting raters look at facial photos and describe what makes them believe one person has slept and one has not could be a first step toward obtaining those cues. Another way would be to objectively assess differences between a face that has slept and one that has not, for example by letting a computer program compare the two. This may also be of benefit for future automated fatigue- and drowsiness-detection systems.

Real-life interactions

The implications for real-life interactions are important and plentiful. One obvious example is a hiring situation, where future studies could couple photographs of sleepy or alert faces with résumés and see whether sleep history actually makes a difference. The evaluations may also look different if there is a professional recruiter making them as opposed to a layperson (Gilmore, et al., 1986). In order to draw conclusions about consequences in real life, one should look at actual interactive situations, such as how clinicians react to people who are sleep deprived versus those who are not. It would also be interesting to see how tired people are treated at work, whether they are left alone and if they feel more left out. One study found a correlation between sleep fragmentation and loneliness, suggesting that people sleep worse when they feel lonely (Kurina et al., 2011), but also opening up for the possibility that people feel more lonely when they sleep worse. Monitoring people’s sleep and social behaviours in everyday life, and experimentally setting up interactions between people who have slept and people who have not slept, would provide valuable information in answering these questions.

How other people perceive us can affect how they behave towards us, which in turn affects how we behave, potentially creating a self-fulfilling prophecy. If someone looks sleepy and we leave them alone, they might feel left out and get grumpy, which confirms our initial reaction to keep our distance. Whether this actually happens, and to what extent, both in personal life and professionally is an empirical question waiting to be answered.

Taking the question of accuracy one step further, it would be interesting to see whether others’ ratings of employability and leadership ability, perhaps operationalized as competence, actually correlate with the cognitive abilities
of the sleep-deprived person. The people who look more tired or sleepy, and less competent, might also be less able to carry out certain mental (and social) tasks. This would provide support for the value of being able to recognize that someone is suffering from sleep loss.

In essence, the field of sleep research would benefit from gearing towards social psychology, seeing as both human interaction and sleep are two major parts of most people's lives, and the two clearly seem to interact. Likewise, the field of social psychology could benefit from knowledge about sleep, not only in studies on first impressions, but also in those focusing on emotion recognition and expression, and social interactions in general.

Concluding remarks

Sleep may be important to keep several cognitive, physiological, and emotional processes functioning optimally, but people still often fail to get the sleep they need. Perhaps these consequences of sleep loss do not feel personally relevant enough to motivate spending more time in bed rather than doing all those things that should be done. How others perceive us, on the other hand, and how they behave towards us, may constitute a more tangible negative effect of not getting enough sleep. What if others perceive you as a worse leader? What if your date is less interested in spending time with you? What if the world finds your face less physically attractive?

Now, are you sure you want to stay up and watch that last episode...?
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