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Sleep, food cravings and taste

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ABSTRACT

Objective: Taste is influenced by factors from our environment, psychology, and from our own physiological state. The objective of the study was to determine whether sleep influences our sense of taste or our cravings for food.
Method: 57 healthy panelists, predominantly of college age, submitted to sleep tracking, and subsequently underwent a series of sensory tests, using basic prototypic tastants, as well as real foods. Panelists were also evaluated to quantify food cravings, using both the Leeds Food Preference Questionnaire, and the Control of Eating Questionnaire.
Results: Umami ($p = 0.025$, $F = 5.301$) and sour ($p = 0.037$, $F = 4.591$) taste were intensified in those rating sleepiness higher, while this group also reported higher implicit wanting for high fat sweet foods ($p = 0.011$, Wald chi-sq = 14.937). Craving for sweet or savory also associated with a number of measures of taste response to real foods.
Conclusions: Results imply that a lack of sleep may induce cravings for unhealthy foods, and that foods high in umami or sour taste may be experienced differently due to alterations in taste function. Results imply that feeding behavior may be influenced by a lack of sleep, acting at least partially through our sense of taste.

1. Introduction

Sleep functions as a restorative process of the brain, and is crucial for our health (Hobson, 1995). Behavioral sleep curtailment has become a major health concern for modern society: more people customarily are sacrificing their sleep, often for work or study (Hicks & Pellegrini, 1991; Beccuti and Pannian, 2011; Matricciani, Olds, & Petkov, 2012). Research has shown that sleep curtailment can increase the chance of developing metabolic disorders including diabetes and obesity (Appelhans et al., 2014; Di Milia, Vandelanotte, & Duncan, 2013). Those with sleep durations less than 6 h, or greater than 8 h have greater diabetes risk (Zizi et al., 2012), possibly due to sleep loss interfering with metabolic or endocrine functions. Sleep is a regulator of neuroendocrine function and glucose metabolism, with lack of sleep leading to negative health consequences such as altered insulin sensitivity, and an imbalance in leptin and ghrelin levels (Spiegel, Tasali, Penev, & Van Cauter, 2004; Beccuti and Pannian, 2011; also see reviews by Van Cauter et al., 2007; Spiegel et al., 2009); factors also linked to taste function (Baquero & Gilbertson, 2011; Dando, 2010; Kawai, Sugimoto, Nakashima, Miura, & Ninomiya, 2000; Shin et al., 2010). Various studies have investigated links between sleep and either cravings for, or intake of, foods. Increased sleep led to a decrease in both overall appetite and the desire for sweet or salty foods in a study of young adults (Tasali, Chapotot, Wroblewski, & Schoeller, 2014). Conversely, adolescents sleeping less than 8 h a day showed significantly increased consumption of calories from fat and carbohydrates (Weiss et al., 2010). Spiegel et al. (2004) demonstrated an enhanced appetite as well as increases approaching significance in reported desire for sweet, starchy and salty foods in those undergoing sleep restriction vs sleep extension. While the total weight of food consumed by panelists in the experiments of Cain, Filtness, Phillips, and Anderson (2015) was unchanged in a model of disturbed sleep (a simulated night shift), participants ate significantly more high-fat foods after sleep manipulation. When sleep deprived, panelists showed a greater desire for high calorie foods, with no change in wanting of low calorie items (Greer, Goldstein, & Walker, 2013), again highlighting a vulnerability for unhealthy eating behavior with sleep loss.

Sleep can be quantified using measures such as sleep duration,

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with sleep quality scores, or via instantaneous subjective ratings of sleepiness. Residential sleep studies or tracking devices are most effective in determining sleep duration, while sleep quality is often measured with scoring systems such as the Pittsburgh Sleep Quality Index (Buysse, Reynolds, Monk, Berman, & Kupfer, 1989), with ratings of sleepiness most regularly quantified using the Stanford (Hoddes, Zarcone, Smythe, Phillips, & Dement, 1973) or Karolinska (Åkerstedt & Gillberg, 1990) sleepiness scales. In a large meta-analysis of several thousand participants, self-reported ratings of sleepiness showed the strongest relation to a panelist's cognitive performance, with sleep quality and sleep duration the next most effective respectively (Dewald, Meijer, Oort, Kerkhof, & Bögels, 2010).

This study sought to test whether a relationship exists between sleep patterns and taste function. A number of groups have reported no link between sleep and taste (Hogenkamp et al., 2013; Smith et al., 2016), however the majority of studies performed to date are limited to testing sweet and/or salty taste; the impact of sleep on umami, sourness, and bitterness remain particularly sparsely studied. Although taste response can predict eating habits (Keller, Steinmann, Nurse, & Tepper, 2002; Noel, Sugrue, & Dando, 2017), and taste is the primary driver of food choice (IFIC, 2017), other factors also contribute to the foods we select. Food cravings refer to an individual's urge to seek out and consume specific foods (Tiggemann & Kemps, 2005). Craving a food can also predict overconsumption of that food (Martin, O'Neil, Tollefson, Greenway, & White, 2008). Thus, as a secondary hypothesis, we sought to examine whether cravings for specific food categories would also associate with taste response to such foods.

2. Methods

2.1. Participants

Recruiting was conducted through the Cornell Sensory Evaluation Center mailing list, on Facebook, and via flyers posted on campus. All parts of the study were approved by Cornell University's Institutional Review Board for human participants. A small cash incentive was offered to each panelist for participation. All participants agreed to use the "Pillow" app (Neybox Interactive, Greece), and to provide us with their sleep data. The study took place in an exam week, where we expected more participants would have less, and lower quality sleep. The study was held for 3 consecutive days in the mornings, where panelists could choose any date, and were only required to attend one session, taking around 30 min to complete. BMI values were also obtained by measuring height and weight before sensory testing (Lohman et al, 1998). BMI was calculated with the formula: BMI = [weight (kg)/height2 (m)], with values varying between 16.5 and 34.0 kg/m^2, with an average of 22.7 (SD = 3.1). A small number of panelists did not complete every test however data were included for all completed measures.

2.2. Sleep data

We preferred for our panelists to represent a free-living population, thus to make an automated measure of sleep duration and quality the smartphone app "Pillow" was used to track panelists. This app utilizes motion sensors and the microphone on participants' devices to generate data on body mobility and ambient noise levels during sleep, with the raw data processed through a probabilistic model. The quality of sleep is calculated via a simplified version of the Pittsburgh Sleep Quality Index. This modification removes self-reported qualitative inputs, using only instrumentally collected data from the participant's time to bed, time to fall asleep, waking time, time in bed and asleep, number of awakenings during the night, and an approximation of breathing rate. Data are reported as a percentage, with higher scores indicating better sleep quality. Participants were required to download the app on their iPhone or iPad, and use it on the night before attending the study. Ratings of sleepiness were also collected on the Stanford Sleepiness Scale (SSS) and Karolinska Sleepiness Scale (KSS), at the beginning and the end of the test respectively. In actuality, ratings were very well correlated ($p < 0.001$), thus the SSS was used for the remainder of analysis. At the end of the study, panelists were also asked how many hours of sleep they usually get, and how long they perceived that they had slept the preceding night, with the difference between these 2 values also examined as a factor in the models to represent a measure of sleep deprivation.

2.3. Sensory testing

Data collection was performed using RedJade sensory analysis software (Tragon Corp, Deerfield, IL), aside from the LFPQ (Leeds Food Preference Questionnaire) data, which was collected on custom software (Finlayson, King, & Blundell, 2007). Panelists performed testing in individual sensory booths. There were four parts to the sensory study, (i) intensity ratings of low and high concentrations of five basic taste solutions, (ii) the Control of Eating Questionnaire (CoEQ), (iii) the LFPQ and (iv) taste intensity ratings of real foods. Tastant solutions were sucrose (sweet, 27 mM and 243 mM), NaCl (salty, 11 mM and 100 mM), citric acid (sour, 0.333 mM and 3 mM), Monosodium Glutamate (MSG) (umami, 3 mM and 27 mM), Quinine HCl (bitter, 0.019 mM and 0.167 mM). Participants rated the perceived intensity of 25 ml samples in a whole mouth, sip and spit procedure, on the gLMS (generalized Labelled Magnitude Scale, Bartoshuk et al., 2004) for each solution. The gLMS provides a measure of taste response normalized across sensory modalities, with scale points: no sensation (0.0), barely detectable (1.4), weak (6.0), moderate (17.0), strong (34.7), very strong (52.5), and strongest imaginable sensation of any kind (100.0). Panelists rinsed their mouths between each sample after expectorating, and tastant order was randomized for each participant. Ratings were divided into two parts with the CoEQ, with 3 sets of samples tested before and 2 after, to assist in combating panelist fatigue. The CoEQ is a validated test of craving control consisting of 21 questions that are used to evaluate one's severity and type of food cravings (Dalton, Finlayson, Hill, & Blundell, 2015). This selection of questions is scored with an algorithm to result in 4 values representing a panelist's degree of craving control, craving for sweet, craving for savory, and positive mood. The LFPQ measures responses to foods by presenting a series of images of a variety of foods which are common in nature, and familiar to participants. The pictures were reviewed and chosen from a prevalidated database to represent foods high or low in fat, sweet, and salt. The LFPQ measures a panelist's explicit liking of a set of foods, via how much this group is chosen, and a panelist's implicit wanting, via how quickly a preference is decided in paired food preference tests. Following this, a series of common foods were presented to the panel for them to rate taste sensations. Each food was common and easy to identify. Sweet and fat were rated with a chocolate bar, sweet and sour were rated with a hard candy, umami and salty were rated with beef jerky, and salty was rated with salted potato chips, all on the gLMS, after which demographic data was collected.

2.4. Statistical analysis

Data were analyzed using t-tests, ANOVAs, Principal Component Analysis, and via generalized linear models, and linear mixed