# Does circadian rhythm affect consumer evaluation for food products? An experimental study

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***Selected Paper prepared for presentation at the 2017 Agricultural & Applied Economics Association Annual Meeting, Chicago, Illinois, July 30-August 1***

**Abstract:**

Empirical evidence shows that circadian rhythm mismatch is a source of cognitive ability depletion. Specifically, recent studies show that circadian match-mismatch may influence individuals' decision making. In this study we investigate whether behavioral changes due to circadian rhythm imply a change in consumers' willingness-to-pay formation for food attributes. We conducted an online choice experiment by manipulating the time of the day we administer the survey. Respondents answered the survey at the time of the day relative to their diurnal preferences (circadian matched) or at a non-preferred time (circadian mismatched). Results from this experiment suggest that circadian rhythm does affect consumers' WTP formation for a food product and corroborate the conjecture of recent studies that researchers should take this aspect into consideration when designing and conducting economic experiments.

**Introduction:**

People have a biological clock, the so called circadian rhythm. People, for example, might be morning or evening types. Morning type people tend to wake up early in the morning, be more active in the morning and go to sleep early at night. On the other hand, evening type people tend to stay up till late at night, prefer working in the evening and wake up late in the morning. In neuroscience, it is well documented that circadian rhythm influences individuals' cognitive performance (Goel et al., 2013). Specifically, studies have shown that circadian mismatch is a source of cognitive resource depletion (Bélanger et al., 2014; Curtis, 2014). Recently, several research have documented that cognitive load influences individuals' decision making in economic settings, suggesting that behaviors such as excessive risk aversion, overly impatience, and anchoring might depend on the availability of individual's cognitive resources (Frederick, 2005; Deck & Jahedi, 2015; Burks et al., 2009; Dohmen et al., 2010; Benjamin et al., 2013; Bergman et al., 2010). There is an increasing consensus among behavioral economists that this aspect might be explained by the fact that individuals have an "intuitive" system and a "reasoning" system (Fudenberg and Levine, 2006; Kahneman 2002; Kahneman 2011; Mukherjee, 2010). The "intuitive system" tends to drive the individuals to adopt impulsive or undesirable behaviors in choice making which are generally regulated by the "reasoning" system. Cognitive resources depletion hinters the ability of the "reasoning system" to regulate decisions, leading, therefore, to less reasoned behavior.

In order to investigate the effect of cognitive load on individuals' choice behavior, researchers usually induce cognitive depletion by using memorization or logical tasks (Benjamin et al., 2013; Deck & Jahedy, 2015). However, contrary to other temporary cognitive depletion tasks, the circadian rhythm is a natural, physical condition which most of the people experience.

Therefore, circadian mismatch is a manipulation task that is less likely to generate inconsistencies in behavior due to learning or adaption (Castillo et al., 2014). For this reason, the effect of circadian timing on individuals' choice behavior is gaining attention among behavioral economists (Castillo et al., 2017; Dickinson & McElroy, 2012; Dickinson & McElroy, 2016). Castillo et al. (2017) conducted two experiments in order to determine the effect of circadian rhythm on (1) individuals' risk preferences and (2) on individuals' rational behavior. The authors found that circadian mismatched individuals were less risk averse, while they did not observe any significant difference in terms of choice consistency behvarior. Dickinson and McElroy (2012) examined how individuals implemented strategic reasoning in a Beauty Contest depending on the time of the day the decisions were made. Results from their experiment show that individuals doing the experiment during their diurnal preferences tended to display higher levels of strategic reasoning. Finally, Dickinson and McElroy (2016) tested the effect of circadian rhythm on greed, trust, and trustworthiness in bargaining games (ultimatum, dictator, and trust games), finding no significant differences in choice behavior across circadian matched and mismatched individuals.

To the best of our knowledge, no previous study has explored the effect of circadian match/mismatch on individuals' preferences and Willingness to Pay (WTP) formation for a good or a service. To fill this void, we conducted an online choice experiment in order to investigate US consumers' WTP for different attributes on cheese products (i.e. mozzarella string cheese) while manipulating the time of the day we administered the survey. Following Dickinson and McElroy (2012) and Castillo et al. (2014), we implemented a two-phase survey, aimed at minimizing endogeneity issues in the interpretation of circadian effect on respondents' choice making.

Results from this study would provide valuable insights on whether researchers should take into account consumers' diurnal preferences when designing and conducting experiments. This is an important issue especially for choice experiments since they are now one of the most popular preference elicitation methods used for policy and welfare analysis. In addition, to the best of our knowledge, this study is the first attempt in the literature to test the effect of circadian timing on consumers' responses in an online experiment framework. Hence, we posit that results from this study would also be of interest for market practitioners in the development of online marketing strategies.

This paper is structured as follows: first, we will describe the experimental procedures and the econometric analysis which were implemented. On the basis of the obtained results, we will then propose some conclusions.

## Experimental Design:

### *The Choice Experiment*

In this study we use a six sticks (1 oz each) Mozzarella String Cheese package as the product in question for two main reasons. First, mozzarella string cheese is one of the most popular cheese products in the U.S. Second, people consume mozzarella string cheese in different times of the day, from the morning to the evening. This aspect made it particularly suitable for our experiment.

The mozzarella string cheese products are charcterized by four attributes: price, Fat Free, Carbon Footprint Label (reducing with Crabon Trust), and the use edible wrappers for the cheese sticks (Table 1).

-- Insert Table1--

The price attribute is represented by four levels: $1.89, $3.59, $5.29, $6.99, which approximately reflect the prices of a package of six mozzarella string cheese sticks in the U.S. market. Each of the non-price attributes is described by two levels: present and absent. The Fat-free attribute was chosen in order to test whether circadian match/mismatch influences individuals' more/less healthy choices. On the other hand, we chose the Carbon Foot Print label since this attribute can be considered as a credence attribute, i.e. individuals cannot personally evaluate this feature before or after consumption. Hence, consumers' valuations of the credence attributes depend on their level of trust in the product claim and the sources of these claims. Studies have shown that circadian time affects individuals' trust behavior in bergaining games (Dickinson & McElroy, 2016). As such, our hypothesis is that trust behavior in the source of information, such as the Carbon Footprint label, might be affected by respondents' circadian rhythm. Finally, the use of edible wrappers was selected as one of the experimental attributes since edile wrappers on cheese products are not present yet on the market in the U.S.[1]. Therefore, assuming that more risk averse individuals tend to choose less a feature of the product that they do not know (Pliner & Hobden, 1992), we implemented the edible wrappers in order to test whether diurnal preferences might affect individuals' choices for a food feature that should be new to them.

The attributes and attributes levels were allocated across sixteen choice tasks according to a D-Optimal design with 97.21% of D-efficiency (Street. et all, 2005). In order to avoid respondents' fatigue in answering to the choice experiment, the sixteen choice tasks were divided into two orthogonal blocks of eight choice tasks each. The respondents were randomly assigned to

[1] Researchers from the USDA have recently developed food wrappers made of casein, a milk protein.

one of the two blocks. Each choice task consisted in two purchasing options, representing two types of mozzarella string cheese, and a “none of these” option (Figure 1).

--Insert Figure 1--

For each of the eight choice tasks, respondents were asked to make a trade-off among the two product alternatives and the opt-out option. Prior to the choice experiment, a brief description of the experimental attributes was provided. In addition, due to the hypothetical nature of our CE, a cheap talk script was also included.

*Circadian Rhythm elicitation:*

As aforementioned, we used a two-phase survey, aimed at minimizing endogeneity issues in the interpretation of circadian effect on respondents’ choice making. Both first and second phases of the survey were conducted online using the Qualtrics panel.

<u>First phase survey:</u>

In this phase we elicited diurnal preferences using the short form of the morning-evening questionnaire (Adan and Almiral, 1991). Data from this first phase were implemented to categorize the respondents into morning and evening types. In addtion, individuals who had not purchased mozzarella string cheese products in the last twelve months have been screened out of the survey. Finally, a sample of 1,520 indviduals took part in this phase, specifically 760 morning type people and 760 evening type people.

Second phase survey:

The second phase was conducted several weeks after the conclusion of the first phase. The selected morning and evening type respondents were then randomly assigned to participate in the second phase survey during the morning (6:00-9:00 AM) or during the evening (8:00-11:00 PM). In this way, two treatments were obtained: respondents who were circadian matched (e.g. morning types responding in the morning and evening types in the evening) and respondents who were circadian mismatched (e.g. morning types responding in the evening and evening types in the morning). A total of 211 respondents participated in the second phase, 144 circadian matched individuals and 67 circadian mismatched individuals. Both the second and the first phases were conducted on Tuesdays, Wednesdays, Thursdays, and Fridays in order to avoid weekend sleep effects that could confound the circadian manipulation. In addition, we implemented the Karolinska Sleepiness Scale (KSS) in order to control for the state of sleepiness while respondents were answering to the choice experiment (Kaida et al., 2006). The KSS is a validated scale where individuals are asked to rate from 1 (“Extremely alert”) to 9 (“Very sleepy, great effort to keep awake, fighting sleep) their temporary level of sleepeness. In table 2 we report descriptive statistics of the KSS for the cricadian matched and circadian mismatched sample.

--Insert Table 2--

Specifically, results for the Pearson Chi square show that the two treatments do not differ in terms of level of sleepiness at the moment of anwering the choice experiment, suggesting that differences in circadian match/mismatch can not be confounded with respondents’ level of sleepiness.

**Econometric Analysis:**

Respondents' preferences and WTPs were analyzed using a discrete choice framework. Discrete choice models are based on the Lancaster's theory of consumer utility (Lancaster, 1966) and the random utility theory (McFadden, 1974) and, therefore they are analysed using Random Utility Models. The basic assumption of the Random Utility Model (RUM) is that consumers make decisions according to the maximization of the utility they can derive from a good or a service. Hence, given a set of alternatives *j* the individual *n* will choose the alternative *j* that will provide the highest utility:

$$U_{nj} > U_{nk} \ \forall \ k \neq j \qquad (1)$$

The choice of the consumer might depend on factors which can be observed by the researcher, such as the selected choice alternative or the attributes of the product, and on factors which are not directly observable. Hence, given a set of choice alternatives *j*, the individual utility $U_{njt}$ can be decomposed at follows:

$$U_{njt} = V_{njt} + \varepsilon_{njt} \qquad (2)$$

where *n* is the index of the respondent, *j* is the index of the different choice alternatives and *t* is the index of the choice situation. $V_{njt}$ is the representative, observable component of total utility, that is the utility that the consumer *n* derives by the attributes and the equivalent values for alternative *j* in choice set *t*, while $\varepsilon_{njt}$ is the stochastic component that resumes all those factors that cannot be observed by the researcher.

Several studies have documented that consumers' preferences for food attributes are heterogeneous (Bazzani et al., 2017; Gracia, 2013; Van Loo et al., 2014). For this reason, in our econometric analysis we implemented a Random Parameter Logit (RPL) model that takes into account taste heterogeneity and the panel structure of the data, given that each respondent answered eight choice tasks. In addition, we specified the utility function in WTP space. Models in WTP space relax the assumption of the price as fixed parameter and have the advantage that the model coefficients can be directly interpreted as marginal WTP (*m*WTP) for the product attributes (Balcombe et al., 2009; Bazzani et al., 2017; Scarpa et al., 2008). For this reason, re-parametrizing the utility function in WTP is particularly suitable in comparing *m*WTP across treatments (Bazzani et al., 2017). Moreover, previous studies showed that more stable and reasonable *m*WTP estimates can be obtained when models re-parametrized in WTP space are implemented in comparison with models parametrized in preference space (Train & Weekes, 2005; Scarpa et al., 2008).

For the two treatments the utility that individual *n* derives from choosing option *j* in choice situation *t* can be specified as follows:

$$U_{njt} = \theta_{njt} (ASC - PRICE_{njt} + \omega_1 FATFREE_{njt} + \omega_2 CARBON_{njt} + \omega_3 EDIBLE_{njt}) + \varepsilon_{njt} \quad (3)$$

where $\theta = \lambda / \alpha$, $\lambda$ is the Gumbel scale parameter and $\alpha$ is the coefficient of price. ASC is the alternative specific constant of the no-buy option. PRICE is a continuous variable populated with the four price levels in the design. FATFREE, CARBON, and EDIBLE are respectively dummy variables for Fat-Free claim, Carbon Footprint Label and the use of edible wrappers. Hence, they take value 1 in case the product carries the claim, 0 otherwise; $\varepsilon_{njt}$ is an unobserved random error term that is i.i.d. Gumbel distributed.

To test for differences across treatments, we specified an extended utility function, which includes a vector of WTPs related to a specific treatment denoted by a dummy variable. Specifically, we identified the treatment as a *dtreatment* binary variable, taking the value 0 for the circadian mismatch treatment and the value 1 for the circadian match treatment. Accordingly, the extended utility function is specified as follows:

$$U_{njt} = \theta_{njt} (ASC - PRICE_{ijt} + \omega_1 FATFREE_{njt} + \omega_2 CARBON_{njt} + \omega_3 EDIBLE_{njt} + \delta_1(ASC *dtreatment) + \delta_2(FATFREE_{njt} *dtreatment) + \delta_3(CARBON_{njt} *dtreatment) + \delta_4(EDIBLE_{njt} *dtreatment)) + \varepsilon_{njt} \quad (4)$$

Where $\delta_1$, $\delta_2$, $\delta_3$, and $\delta_4$ respresent the treatment effect respectively on the alternative specific constant of the no-buy option (ASC) and FATFREE, CARBON, and EDIBLE attributes. The significance of the estimated $\delta_1$ , $\delta_2$, $\delta_3$, $\delta_4$, and their signs establish the effect of the treatment on the WTP estimates of interest. Specifically, $\delta_1$ allows us to estimate the effect of the tratment of the total WTP for the product (Lusk & Schroeder, 2004), while $\delta_2$, $\delta_3$, $\delta_4$ determine if and how the marginal WTP for FATFREE, CARBON, and EDIBLE attributes differed across the the two treatments respectively.

**Results:**

In table 3 estimates from the RPL models in WTP space are reported. Specifically, we compare WTP estimates from the circadian match treatment (Model 1), circadian mismatch treatment (Model 2) and the pooled sample (Model 3).

--Insert Table 3--

In all the models, the constant, ASC, is ,as expected, negative and statistically significant at the 0.01 level; hence, the utility that consumers derive from choosing neither of the proposed alternative products is lower than the utility from buying one of them. Also, the price coefficient is negative, indicating that increasing increments on the price variable decrease the associated utility level provided by the choice of the product. Regarding the Fat-Free claim, we observe that circadian matched individuals (Model 1) tend to have a negative WTP premium, while Fat-Free coefficient of the circadian matched treatment is not statistically significant. From the fourth column of table 3 we observe that the interaction term between the treatment and the Fat-Free attribute is, indeed, statistically significant, indicating that circadian matched individuals have a significant lower *m*WTP for the fat-free cheese in comparison with circadian mismatched individuals. This result is in contrast with our expectations, since previous literature shows that individuals tend to make healthier choices when they are matched with their circadian rhythm (De Assis et al., 2003). We also observe a significant negative interaction between the Carbon Footprint Label and the treatment effect. This indicates that circadian matched participants are willing to pay more for the product characterized by the Carbon Footprint Label in comparison with the circadian mismatched group. This might, then, suggest that circadian mismatched individuals choose the Carbon Footprint Label, possibly due to the fact that they trust more the source of information than what circadian matched individuals do. However, the preference for the Carbon Footprint label and therefore for safeguarding the natural resources might also be interpreted as a sign of pro-social behavior. If this interpretation is given, then we might conclude that our results are in contrast with previous studies which show that cognitive depletion tends to lead to less altruistic choices (Hauge et al., 2014; Cappelletti et al. 2011). On the other hand, we do not find any significant differences across the two treatments in terms of preferences for the novel attribute, i.e. edible wrappers. In the case of both treatments, individuals have a negative WTP premium for the use of edible wrappers on string cheese. Finally, table 3 shows that the treatment effect has a significant interaction with the alternative constant of the no-buy option. Specifically, the negative sign of the interaction suggests that circadian matched individuals tend to have a higher total WTP for the product in comparison with circadian mismatched participants.

**Conclusions:**

In this study we tested for the first time in the literature whether circadian rhythm affects consumers' valuation for food product characteristics. This is an important aspect in designing economic experiments since circadian mismatch is a natural source of cognitive depletion, which most of the people experience. We conducted an online choice experiment to investigate consumers' WTP formation for food attributes on mozzarella string cheese products depending on their diurnal preferences.

Findings from this study suggest that circadian rhythm influences consumers' food choice behavior. Specifically, our results show that mismatched consumers tend to have a higher marginal WTP for the product attributes, while circadian matched consumers show a higher total WTP for the product.

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**Tables**

**Table 1: Attributes and Attribute Levels**

| Attributes | Attribute Levels |
|---|---|
| Fat Free claim | - Present |
| | - Absent |
| Carbon Foot Print Label | - Present |
| | - Absent |
| Edible Wrappers claim | - Present |
| | - Absent |
| Price | - $1.89 |
| | - $3.59 |
| | - $5.29 |
| | - $6.99 |

**Table 2: Karolinska Sleepiness Scale: Descriptive statistics (%)**

| Levels | Circadian Matched | Circadian Mismatched |
|---|---|---|
| 1 | 9.09 | 7.46 |
| 2 | 19.58 | 7.46 |
| 3 | 23.78 | 23.88 |
| 4 | 18.18 | 17.91 |
| 5 | 9.09 | 7.46 |
| 6 | 13.99 | 22.39 |
| 7 | 3.50 | 7.46 |
| 8 | 2.80 | 5.97 |
| 9 | 0.00 | 0.00 |
| *Pearson chi2(7) = 9.1929 Pr = 0.239* | | |

**Table 3: Random Parameter Logit Estimates in WTP space**

| | **Model 1 - Circadian Matched** | | | **Model 2 - Circadian Mismatched** | | | **Model 3 – Pooled sample** | | |
|---|---|---|---|---|---|---|---|---|---|
| **Attributes** | Coeff. | SE | z-value | Coeff. | SE | z-value | Coeff. | SE | z-value |
| Fat-Free | -0.266*** | 0.216 | 3.33 | -.0001 | 0.158 | 0.00 | -0.011 | 0.116 | -0.10 |
| Carbon | 0.054 | 0.072 | 0.75 | 0.382** | 0.167 | 2.28 | 0.349** | 0.139 | 0.10 |
| Edible | -0.721*** | 0.216 | -3.33 | -0.639** | 0.26 7 | -2.39 | -0.689* | 0.371 | -1.86 |
| Price | -0.794*** | 0.298 | -26.67 | -0.915*** | 0.184 | -4.96 | -0.820*** | 0.025 | -32.73 |
| ASC | -3.867*** | 0.176 | -21.94 | -3.845*** | 0.743 | -5.17 | -3.514*** | 0.163 | -21.43 |
| **Treatment effect** | | | | | | | | | |
| *FATFREE *dtreatment* | | | | | | | -0.253* | 0.142 | -1.78 |
| *CARBON *dtreatment* | | | | | | | -0.300* | 0.157 | -1.90 |
| *CARBON *dtreatment* | | | | | | | 0.006 | 0.349 | 0.02 |
| *ASC *dtreatment* | | | | | | | -0.496*** | 0.151 | |
| **Model fit Criteria** | | | | | | | | | |
| Log-likelihood | | | -887.99094 | | | -401.95138 | | | -1291.53864 |
| N of choices | | | 1152 | | | 536 | | | 1688 |

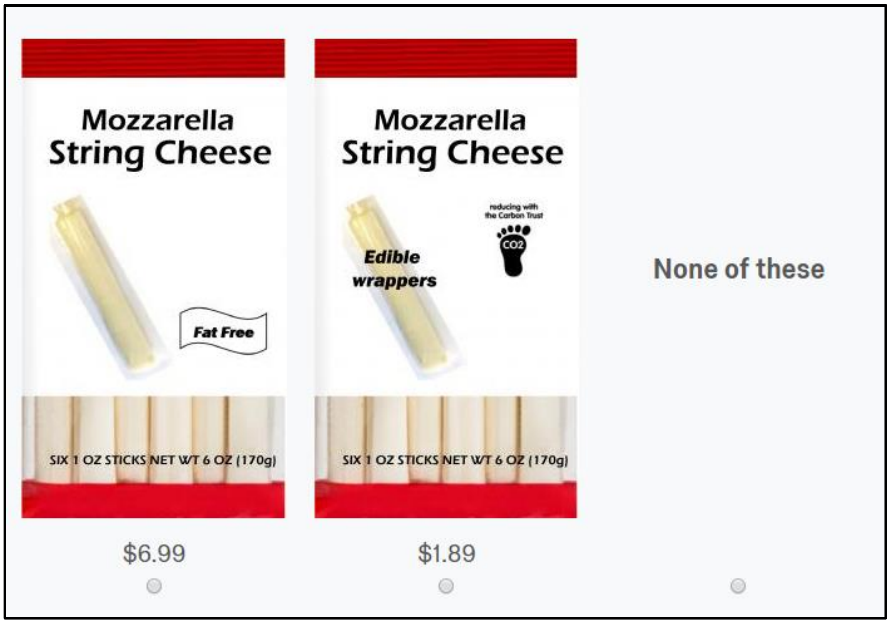


**Figure 1: Example of a choice task**