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# Food cravings in everyday life: An EMA study on snack-related thoughts, cravings, and consumption

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ABSTRACT

Food craving refers to an intense desire to consume a specific food and is regularly experienced by the majority of individuals. Yet, there are interindividual differences in the frequency and intensity of food craving experiences, which is often referred to as trait food craving. The characteristics and consequences of trait and state food craving have mainly been investigated in questionnaire-based and laboratory studies, which may not reflect individuals' behavior in daily life. In the present study, sixty-one participants completed the Food Cravings Questionnaire-Trait-reduced (FCQ-T-r) as measure of trait food craving, followed by seven days of Ecological Momentary Assessment (EMA), during which they reported snack-related thoughts, craving intensity, and snack consumption at five times per day. Results showed that 86 percent of reported snacks were high-caloric, with chocolate-containing foods being the most often reported snacks. Individuals with high FCQ-T-r scores (high trait food cravers, HCs) thought more often about high-calorie than low-calorie snacks whereas no differences were found in individuals with low FCQ-T-r scores (low trait food cravers, LCs). Further, the relationship between craving intensity and snack-related thoughts was stronger in HCs than in LCs. Higher craving intensity was associated with more consumption of snacks and again this relationship was stronger in HCs than in LCs. Finally, more snack-related thoughts were related to more frequent consumption of snacks, independent of trait food craving. Thus, HCs are more prone to think about high-calorie snacks in their daily lives and to consume more snack foods when they experience intense cravings, which might be indicative of a heightened responding towards high-calorie foods. Thus, trait-level differences as well as snack-related thoughts should be targeted in dietary interventions.



## 1. Introduction

In today's obesogenic environment, sugary and fat-rich snack foods are often consumed at quantities that go beyond homeostatic needs (Cleobury & Tapper, 2014; McKiernan, Houchins, & Mattes, 2008), pointing to the relevance of non-homeostatic determinants of food intake (Lowe & Butryn, 2007). One of these determinants is the experience of food craving, which refers to an intense desire to consume a specific food (White, Whisenhunt, Williamson, Greenway, & Netemeyer, 2002) and which can occur in the absence of hunger (Pelchat & Schaefer, 2000). Food cravings are prevalent in societies characterized by abundant food environments (Pelchat, 1997; Weingarten & Elston, 1991) and craved foods are usually high in sugar and fat, with chocolate being the most frequently craved food in Western societies (Rozin, Levine, & Stoess, 1991). Food cravings are quite specific in that they can be satisfied only by the craved—or very similar—food (Bruinsma & Taren, 1999). As food cravings have been associated with past dieting failures (Meule, Westenhöfer, & Kübler, 2011) and prospectively predict increased food intake and weight gain (Boswell & Kober, 2016; Meule, Richard, & Platte, 2017), knowledge about the characteristics of food cravings is relevant for health behaviors in various fields.

Food cravings are multidimensional experiences with cognitive, motivational, and behavioral facets (Cepeda-Benito, Gleaves, Williams, & Erath, 2000). According to the elaborated intrusion theory of desire, craving is a result of a cognitive elaboration of intrusive thoughts about a desired object (Kavanagh, Andrade, & May, 2005; May, Andrade, Panabokke, & Kavanagh, 2004),

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highlighting the role of food-related thoughts as a prerequisite for the emergence of food cravings. Thus, food cravings are not necessarily triggered by the presence of food stimuli, but can also occur spontaneously through mental imagery of the craved foods (Hallam, Boswell, DeVito, & Kober, 2016). These thoughts can also trigger consumption of the craved food, particularly when cravings are intense (Appelhans, French, Pagoto, & Sherwood, 2016; Hofmann & Van Dillen, 2012; Papies, Stroebe, & Aarts, 2007). There are also marked and stable interindividual differences in the frequency and intensity of food craving experiences, suggesting that some individuals think more frequently, crave more intensely and—as a consequence—likely consume more snack foods than others. Recent theorizing refers to such differences as tonic or *trait food craving* (Boswell & Kober, 2016; Hallam et al., 2016). Importantly, whereas state food craving is exclusively experienced as transient state in a particular moment, trait food craving refers to the experience of food cravings in general.

Laboratory and questionnaire-based studies revealed that individuals with elevated levels of trait food craving (i.e., high trait food cravers) seem to have a preference for high-calorie foods and are more susceptible to experience food cravings spontaneously or when confronted with external food cues. For instance, relative to low trait food cravers, high trait food cravers displayed an implicit approach tendency towards high-calorie foods (Brockmeyer, Hahn, Reetz, Schmidt, & Friederich, 2015) and showed more reward-related brain activity during food picture viewing (Ulrich, Steigleder, & Grön, 2016). High trait food cravers also reported higher craving intensity when they were asked to imagine their favorite food (Tiggemann & Kemps, 2005) or were exposed to pictures of palatable foods (Meule, Hermann, & Kübler, 2014; Meule, Skirde, Freund, Vögele, & Kübler, 2012). Similarly, high trait chocolate cravers displayed more positive implicit attitudes towards chocolate (Richard, Meule, Friese, & Blechert, in revision), higher reward-related brain activations during thoughts about chocolate (Miedl, Blechert, Meule, Richard, & Wilhelm, submitted), and had difficulties disengaging their attention from chocolate cues (Kemps & Tiggemann, 2009).

Although experiencing a food craving does not always result in subsequent food intake, previous studies reported positive associations between state (Meule & Hormes, 2015) and trait food craving (e.g., Martin, O'Neil, Tollefson, Greenway, & White, 2008) with consumption of the craved food in the laboratory. However, various situational and individual factors can affect whether craved foods are actually consumed (Hill, 2007). For example, the moderating effect of trait food craving on the relationship between state food craving and subsequent consumption has received little attention. Thus, further research is needed on how closely state cravings, thoughts about foods, and food consumption are interrelated as a function of trait food craving in everyday life.

Previous studies on the assessment of food cravings in everyday life, however, used paper-and-pencil methods such as the craving record sheet (Hill, Weaver, & Blundell, 1991). Here, participants entered craving episodes by hand each time they had felt an urge to consume a specific type of food regardless of consumption. It was found that momentary cravings co-occurred with thoughts about craved foods or the presence of these foods. Moreover, these cravings were often followed by consumption (Hill & Heaton-Brown, 1994). In a more recent study, both trait-level and state-level cravings were associated with consumption (Forman, Hoffman, Juarascio, Butryn, & Herbert, 2013), demonstrating the behavioral consequences of food cravings as well as the presence of interindividual differences. Similarly, total energy intake was higher in female trait food cravers than in non-cravers in a study using a three-day food record (Lafay et al., 2001), which mainly resulted from consumption of between-meal snack foods.

Although these studies provided useful information about food cravings in naturalistic settings, findings are limited by shortcomings of paper-and-pencil measurements, such as low compliance rates and under-reporting of craving episodes (Berkman, Giuliani, & Pruitt, 2014), decreases in compliance across the study period (Massey & Hill, 2012), or backfilling of past events (Stone, Shiffman, Schwartz, Broderick, & Hufford, 2003). Smartphone-based Ecological Momentary Assessment (EMA) in daily life may solve most of these limitations by including electronic prompting and, thus, appear suitable to address transient phenomena (i.e., state food cravings). In addition, hierarchical linear modeling was used in the current study to acknowledge both between-person (here: trait food craving) and within-person information (here: associations between craving intensity, snack-related thoughts, and consumption). Specifically, participants completed the Food Cravings Questionnaire-Trait-reduced (FCQ-T-r), followed by seven days of EMA by use of signal-contingent sampling. At five times per day, they indicated the amount of thoughts about snacks, craving intensity, and snack consumption via their smartphone devices.

The current study had three aims for characterizing food cravings in everyday life. A first aim was to examine the type of snack foods that participants craved most frequently. Based on previous questionnaire-based studies (Rozin et al., 1991; Weingarten & Elston, 1991), it was expected that the majority of craved snacks would be high-caloric and that the most frequently craved food category would be chocolate. A second aim was to expand the conceptual understanding of food cravings outside the laboratory. Specifically, the interrelations between thoughts about snacks, craving intensity, and snack consumption were examined (arrows A, B, and C in Fig. 1A). Given that a cognitive elaboration of food-related thoughts is essential for the emergence of food craving (Kavanagh et al., 2005), it was hypothesized that episodes with more snack-related thoughts would be characterized by higher craving intensity. As food cravings usually involve high-calorie foods, it was expected that the relationship between thoughts about snacks and craving intensity would be particularly pronounced when energy-dense snack foods were thought about. As thoughts about food and more intense food cravings are associated with higher intake of the craved food (Forman et al., 2013; Hill & Heaton-Brown, 1994; Meule & Hormes, 2015), it was further expected that higher craving intensity (arrow B in Fig. 1A) and more thoughts about snacks (arrow C in Fig. 1A) would result in higher snack consumption. A third aim was to examine associations between trait food craving and type of craved snacks, thoughts about snacks, craving intensity, and consumption of snacks (solid gray arrows in Fig. 1A), which would be indicative of the ecological validity of the concept of trait food craving. Based on previous laboratory and questionnaire-based studies (Brockmeyer et al., 2015; Martin et al., 2008; Meule, Hermann, et al., 2014; Richard et al., in revision), it was expected that individuals with high scores on the FCQ-T-r (i.e., high trait food cravers) would report more frequent thoughts about high-calorie snacks, crave more intensely, and also consume more snack foods than low trait food cravers. Finally, it was explored whether trait food craving moderated associations between thoughts about snacks, craving intensity, and consumption of snacks (dashed gray arrows in Fig. 1A). Specifically, it was assumed that the relationships between craving intensity, thoughts about snacks, and snack consumption may be more pronounced in high trait food cravers than in low trait food cravers.

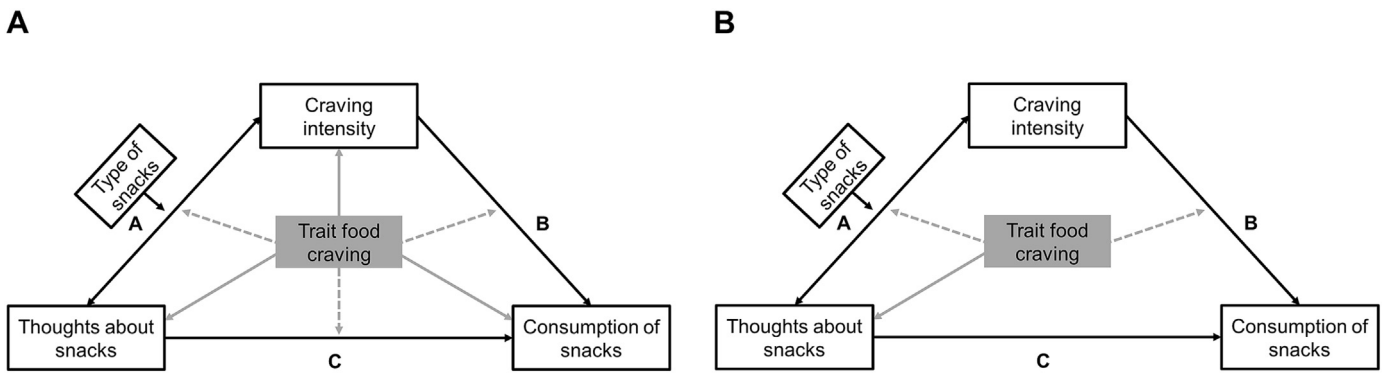


**Fig. 1.** (A) Conceptual model of the interrelations between craving intensity, thoughts about snacks, and consumption as a function of trait food craving. White boxes and black arrows illustrate effects of within-person predictors. The gray box and gray arrows illustrate effects of the between-person predictor (i.e., scores on the Food Cravings Questionnaire-Trait-reduced; FCQ-T-r). Arrows pointing on boxes represent main effects of predictors (e.g., more intense cravings and/or more frequent snack-related thoughts might be related to greater consumption of snacks; arrows B and C). Arrows pointing on arrows represent moderating effects of one predictor on the relation between two others (e.g., the relation between craving intensity and thoughts about snacks might be more pronounced in individuals with high FCQ-T-r scores). The double-headed arrow indicates that variables might be mutually interchangeable (arrow A). Dashed arrows indicate possible cross-level interactions of between- and within-person predictors. Type of snacks refers to the categorization of snacks into high- and low-caloric. (B) Empirical model of the interrelations between craving intensity, thoughts about snacks, and consumption as a function of trait food craving. As opposed to the conceptual model, only significant main and interactive effects are displayed. Craving intensity and type of snack predicted thoughts about snacks (arrow A). Craving intensity and thoughts about snacks predicted consumption of snacks (arrows B and C). High trait food cravers thought more frequently about high-calorie snack foods than low-calorie snack foods (gray arrow). Further, high trait food cravers showed stronger relationships between snack-related thoughts and craving intensity (dashed arrow on arrow A) and between craving intensity and snack consumption (dashed arrow on arrow B).

**Table 1**
Descriptive statistics of Level 1 and Level 2 variables with means, standard deviations, and ranges.

| Variable | *M* | *SD* | Minimum | Maximum |
|---|---|---|---|---|
| **Level 1 (occasions)** | | | | |
| Hunger | 39.3 | 22.3 | 0.00 | 100 |
| Thoughts about snacks | 2.11 | 1.59 | 1.00 | 15.0 |
| Craving intensity | 46.6 | 21.5 | 0.00 | 100 |
| Consumption of snacks | 1.02 | 0.97 | 0.00 | 9.00 |
| **Level 2 (participants)** | | | | |
| Food Cravings Questionnaire-Trait-reduced | 39.5 | 11.4 | 22.0 | 67.0 |

*Notes.* Descriptive statistics of thoughts about snacks including signals for which participants specified not having thought about snacks were $M = 0.87$, $SD = 1.46$, range: 0.00–15.0.

## 2. Methods

### 2.1. Participants

Sixty-six university students were recruited through flyers shared on social media platforms, bulletin boards, and students' mailing lists. The following inclusion criteria were defined: a) female, b) aged between 18 and 30 years, c) no self-reported lifetime mental disorders. Five participants were excluded due to either technical failures with the smartphone device ($n = 1$), response rates < 50% ($n = 2$), or not following the study protocol correctly ($n = 2$). The final sample consisted of 61 participants (mean age = 21.6 years, $SD = 2.47$; mean body mass index = 21.2 kg/m$^2$, $SD = 2.50$).[1] All participants signed informed consent before commencing the study. Ethical approval for the study was granted by the ethics commitee of the University of Salzburg.

[1] Including age as a covariate revealed that it was negatively associated with snack-related thoughts ($\beta_{10} = -0.03$, $p = 0.029$) and snack consumption ($\beta_{10} = -0.07$, $p = 0.043$). However, age neither interacted with the predictor variables (i.e., craving intensity, calorie type, snack-related thoughts, or trait food craving; all $ps \geq 0.499$) nor did it change the pattern and significance of the results. Thus, results are presented without age as covariate.

### 2.2. Questionnaires

#### 2.2.1. Food Cravings Questionnaire-Trait-reduced

The FCQ-T-r (Meule, Hermann, et al., 2014) was used to measure the frequency and intensity of food craving experiences in general. It consists of 15 items (e.g., "I find myself preoccupied with food.", "If I eat what I am craving, I often lose control and eat too much."), and responses are scored on a 6-point scale (from 1 [*never/not applicable*] to 6 [*always*]). Higher scores indicate more frequent and intense food craving experiences. The FCQ-T-r demonstrated high retest-reliability over six months (Meule, Beck Teran et al., 2014), supporting the stability of trait-level food craving experiences. Internal consistency was $\alpha = 0.907$ in the current study.

#### 2.2.2. Craving for high-calorie foods

Participants were given a list of 10 high-calorie snacks (chocolate, ice cream, pizza, noodles, pastries, cookies, sweets, chips, French fries, cake; Meule, Vögele, & Kübler, 2012) to examine frequency of craving experiences for specific foods. They were asked to indicate how often they generally experience an intense desire to consume each of the listed foods on a 6-point scale (1 [*never/not applicable*] to 6 [*always*]).

### 2.3. EMA measures

#### 2.3.1. Snack-related thoughts, craving intensity, and consumption

At each of the five daily prompts, participants indicated how often they had thought about a snack since the last prompt by numerically entering the number of thoughts about snack foods. If participants reported at least one (or more) snack-related thought, they were asked to name the snack they had thought about in a text box. Snacks were defined as foods that were not consumed as part of a principal meal (i.e., breakfast, lunch, or dinner). We explicitly did not constrain snack foods to specific categories, allowing the participants to freely report every snack they had thought about. Snack-related thoughts should be entered regardless of an actual consumption. Participants next rated their desire to consume the snacks (i.e., craving intensity) they had thought about on a continuous slider (from 0 [*not at all intense*] to 100 [*very intense*]). Further, they specified the number of snack thoughts that had internally and spontaneously been evoked (i.e., in the absence of external triggers such as the sight or smell of foods). Lastly, participants reported the number of consumed snacks during the respective period since the last prompt without specifying the type of snack they had consumed. Descriptive statistics of study variables are presented in Table 1.

#### 2.3.2. Principal meals and hunger

Principal meals were assessed so that participants would be able to differentiate thoughts about snacks (i.e., amount, type, and intensity) from other eating episodes (Massey & Hill, 2012). Participants reported how often they had thought about a principal meal since the last prompt by numerically entering the number of thoughts about principal meals. Afterwards, they were asked whether and, if so, what kind of principal meal (breakfast, lunch, or dinner) they had eaten. Further, participants rated their hunger since the last prompt on a continuous slider (from 0 [*not at all hungry*] to 100 [*very hungry*]).

### 2.4. Procedure

Participants completed a set of questionnaires online, including demographic questions and questions on trait food craving (i.e., FCQ-T-r and craving for high-calorie foods). Next, they were trained on the EMA protocol, the usage of the smartphone application, and some specific concepts (e.g., distinction between principal meals and snacks as well as definition of food craving as an intense desire to consume a specific type of food) in a face-to-face session or telephone call. Participants completed seven days of EMA, preceded by a training day (data discarded). The signal-contingent protocol implemented five daily signal times (set at 10 a.m., 1 p.m., 4 p.m., 7 p.m., and 10 p.m.). Delayed responses to signals triggered reminders every 10 min until 1 h had elapsed. At each prompt, participants answered questions regarding their current hunger, thoughts about principal meals and snack foods, craving intensity, and snack consumption. At the end of the study, participants completed questions about reactivity and were reimbursed with course credits or €15,-.

[2] There were two exceptions to this rule: crispbread (334 kcal/100 g) and rusk (365 kcal/100 g), which have a high energy density per 100 g, were classified as low-calorie snacks as they have a small recommended portion size (e.g., 25 g). Low-calorie snacks ranged from tomato (17 kcal/100 g) to raw ham (145 kcal/100 g). High-calorie snacks ranged from jam sandwich (150 kcal/100 g) to peanut butter (626 kcal/100 g). Low-calorie snacks ($M = 59.6$ kcal/100 g, $SD = 25.2$) and high-calorie snacks ($M = 406$ kcal/100 g, $SD = 114$) differed in kcal/100 g, $t_{(764)} = 30.1$, $p < 0.001$.

### 2.5. Data analyses

Reported snacks were categorized as high- or low-caloric by examining energy density (kilocalories per 100 g).[2] If participants specified more than one snack they had thought about per prompt, calorie content was averaged over all snacks reported per signal. The type of snacks reported in the current study are displayed in Table 2.

To analyze the nested, longitudinal structure of the data and to test the conceptual model (Fig. 1A), hierarchical linear models were applied using the software HLM7 (Raudenbush, Byrk, & Congdon, 2011). When participants reported no thoughts about snacks (indicated by 0), the respective prompts were disregarded because there were no corresponding data for craving intensity and consumption (Table 1). To test whether the amount of thoughts about snacks changed across the study period (i.e., reactivity to the EMA measures), the effect of measurement point (i.e., days across the study period; ranging from 0 [day 1] to 6 [day 7]) on thoughts about snacks was tested at Level 1.

To address the first aim (i.e., types of craved snacks foods) and second aim (i.e., interrelations between thoughts about snacks, craving intensity, and consumption of snacks) the following set of analyses was run: snack-related thoughts, craving intensity, and consumption were modeled within individuals at Level 1 (arrows A, B, and C in Fig. 1A). Specifically, craving intensity was modeled as predictor of thoughts about snacks at Level 1 (Table 3). In a next step, type of snacks (0 = low-calorie, 1 = high-calorie) was modeled as a further Level 1 predictor (Table 4). Last, thoughts about snacks, craving intensity, and their *z*-standardized interaction were modeled as predictors for consumption of snacks at Level 1 (Table 5). As participants were not asked to specify the snacks they had consumed, type of snack was not considered as a predictor in the last analysis.

To address the third aim (i.e., ecological validity of trait food craving), FCQ-T-r scores were added to previous analyses at Level 2 to examine main effects (solid gray arrows in Fig. 1A) and moderating effects (dashed gray arrows in Fig. 1A) on the interrelations of craving intensity, snack-related thoughts, and consumption (Tables 3–5). Subsequently, to control for general feelings of hunger, reported hunger level was entered as additional Level 1 predictor for thoughts about snacks and consumption, respectively. The five signals per day (Level 1) were nested within participants at Level 2. Slopes and intercepts were allowed to vary randomly across participants. The *z*-standardized predictors as well as the variables type of snacks and measurement point were entered uncentered into the models. All other Level 1 predictors were person-mean centered and Level 2 predictors were grand-mean centered. More detailed information on model equations and their interpretation can be found in the appendix.

## 3. Results

### 3.1. Compliance and reactivity

Participants responded to 1870 signals of all possible EMA prompts ($N = 2135$), reflecting a compliance rate of 87.6% ($SD = 8.87\%$, range: 60.0–100%). Among these signals, participants indicated at least one snack-related thought for 768 (41.1%) prompts and consumption of at least one snack for 558 (29.8%) prompts. As participants were allowed to enter more than one snack they had thought about, a total of 1057 distinguishable snack foods were counted (Table 2). No effect of measurement point was found on the amount of snack-related thoughts ($\beta_{10} = -0.05$, $p = 0.155$), indicating that individuals did not alter their behavior in response to the EMA measures over time. Similarly, when asked

**Table 2**
Frequency of food cravings for specific foods reported prior to the study (means and standard deviations) and snacks reported during ecological momentary assessment (absolute count of snacks and percentages).

| Categories | *M* (*SD*) | Absolute count of snacks | % of total |
|---|---|---|---|
| Chocolate-containing foods | 3.49 (1.25) | 277 | 26.2 |
| Sweets | 3.26 (1.18) | 72 | 6.81 |
| Pizza | 2.82 (1.06) | 8 | 0.76 |
| Pasta | 2.70 (1.10) | 7 | 0.66 |
| Cookies | 2.61 (0.97) | 103 | 9.74 |
| Pastries | 2.52 (0.96) | 117 | 11.1 |
| Others | 2.52 (1.50) | 141 | 13.3 |
| Cake | 2.49 (0.98) | 52 | 4.92 |
| Chips | 2.46 (1.03) | 59 | 5.58 |
| Ice cream | 2.30 (0.96) | 31 | 2.92 |
| French fries | 2.16 (0.93) | 2 | 0.19 |
| Nuts | – | 24 | 2.26 |
| Beverages | – | 25 | 2.36 |
| Fruits and vegetables | – | 139 | 13.2 |

*Notes.* Absolute number of reported snacks was $N = 1057$. Regarding the amount of snacks per category (in %), the number of specific snacks that participants reported having thought about was divided by the number of all mentioned snacks (differing number of thoughts about snacks per signal not considered here). Frequency of food cravings for specific foods was examined on a scale from 1 (*never/not applicable*) to 6 (*always*). Nuts, beverages, fruits, and vegetables were not assessed prior to the study, but were reported during EMA. "Others" comprises foods that were not classifiable (e.g., cereals, soup, sushi).

**Table 3**
Coefficients (β) with robust standard errors (SE) and p-values of the mixed model with craving intensity as a predictor at Level 1 and trait food craving as a predictor at Level 2 on thoughts about snacks.

| Model | Coefficient ß (*SE*) | *p* |
|---|---|---|
| **Thoughts about Snacks with Level 1 predictors** [a] | | |
| Intercept ($\beta_{00}$) | 2.01 (0.12) | **<0.001** |
| Craving intensity ($\beta_{10}$) | 0.02 (0.004) | **<0.001** |
| **Thoughts about Snacks with Level 1 and Level 2 predictors** [b] | | |
| **Level 1** | | |
| Intercept ($\beta_{00}$) | 2.01 (0.11) | **<0.001** |
| Craving intensity ($\beta_{10}$) | 0.02 (0.004) | **<0.001** |
| **Level 2** | | |
| Trait food craving ($\beta_{01}$) | 0.03 (0.01) | **0.002** |
| **Cross-level interactions** | | |
| Trait food craving × craving intensity ($\beta_{11}$) | 0.001 (0.0004) | **0.019** |

*Notes. P*-values < 0.050 are printed in boldface. More details on interpretation of the model equations can be found in the appendix.

[a] Level 1 model equation: thoughts about $\text{snacks}_{ij} = \pi_{0j} + \pi_{1j}$ (craving intensity) + $e_{ij}$; Level 2 model equations: $\pi_{0j} = \beta_{00} + r_{0j}$; $\pi_{1j} = \beta_{10} + r_{1j}$.

[b] Level 1 model equation: thoughts about $\text{snacks}_{ij} = \pi_{0j} + \pi_{1j}$ (craving intensity) + $e_{ij}$; Level 2 model equations: $\pi_{0j} = \beta_{00} + \beta_{01}$ (trait food craving) + $r_{0j}$; $\pi_{1j} = \beta_{00} + \beta_{11}$ (trait food craving) + $r_{1j}$.

about reactivity at the end of the study, participants reported that the prompts did not change their thoughts about snack foods ($M = 4.30$, $SD = 2.51$ on a scale ranging from 1 [*not at all*] to 11 [*very much*]).

### 3.2. Aim 1: Types of craved snack foods

Our first aim was to examine the characteristics of momentary cravings (i.e., frequency and specificity) in the individuals' daily routines. On average, individuals thought about 5.75 snacks ($SD = 5.08$) and consumed 2.67 snacks ($SD = 2.27$) per day. In total, 107 (14.0%) prompts contained low-calorie snacks and 659 (86.0%) prompts contained high-calorie snacks, that is, participants generally reported more thoughts about high-calorie snacks than low-calorie snacks (Fig. 2A). Chocolate-containing foods were most frequently reported in both self-report prior to the study and during EMA, accounting for 26.3% of all reported snacks (Table 2).

### 3.3. Aim 2: Interrelations between thoughts about snacks, craving intensity, and consumption of snacks

Our second aim was to investigate the interrelations of craving intensity, snack-related thoughts, and consumption within participants. As expected, higher craving intensity co-occurred with frequent thoughts about snacks (Table 3; arrow A in Fig. 1B). When adding type of snacks to this model, the relation between craving intensity and thoughts about snacks remained significant and type of snacks additionally predicted thoughts about snacks. As low-calorie snacks were coded with 0 and high-calorie snacks with 1, the positive coefficient indicates that individuals generally thought more often about high-calorie snacks than low-calorie snacks in daily life (Table 4). When modeled separately, both thoughts about snacks ($\beta_{10} = 0.22$, $p < 0.001$) and craving intensity ($\beta_{20} = 0.02$, $p < 0.001$) were positively associated with consumption. Furthermore, thoughts about snacks, craving intensity, and their interaction (trend level; $p = 0.051$) predicted consumption of snacks (Table 5; arrows B and C in Fig. 1B), that is, when both thoughts about snacks and craving intensity were high, it resulted in higher consumption of snacks (Fig. 2B).

### 3.4. Aim 3: Ecological validity of trait food craving

Our third aim was to examine main effects and moderating effects of trait food craving on craving intensity, snack-related thoughts, and consumption. Higher FCQ-T-r scores were associated with more thoughts about snacks (Table 3; gray arrow in Fig. 1B). Furthermore, trait food craving moderated the effect of craving intensity on thoughts about snacks (Table 3; Fig. 2C) such that the association between craving intensity and thoughts about snacks was stronger in individuals with high FCQ-T-r scores than in those with low scores (dashed arrow on arrow A in Fig. 1B). Trait food craving also moderated the association between type of snacks and thoughts about snacks (Table 4) such that individuals with high FCQ-T-r scores reported more thoughts about high-calorie snacks than low-calorie snacks, whereas no differences were found in individuals with low FCQ-T-r scores (Fig. 2D). When craving intensity was modeled as an outcome, there was no relation between trait food craving and craving intensity ($\beta_{01} = -0.05$, $p = 0.746$), that is, individuals with high FCQ-T-r scores did not experience more intense cravings for snack foods in general. Finally, trait food craving moderated the association between craving intensity and consumption of snacks (Table 5; Fig. 2E) such that the association was more pronounced in individuals with high FCQ-T-r scores than in those with low scores (dashed arrow on arrow B in Fig. 1B). Trait food craving was neither related to consumption of snacks in general nor did it moderate the relation between thoughts about snacks and consumption of snacks. There was also no three-way interaction between trait food craving, thoughts about snacks, and craving intensity (Table 5).

### 3.5. Controlling for hunger as a level 1 predictor

When modeled separately, hunger was positively related to thoughts about snacks ($\beta_{10} = 0.01$, $p = 0.030$). However, this relation was not significant ($\beta_{10} = 0.004$, $p = 0.141$) when craving intensity and type of snacks were simultaneous predictors for thoughts about snacks (all $ps \leq 0.003$). Hunger was unrelated to consumption of snacks when modeled separately ($\beta_{10} = 0.0002$, $p = 0.873$), but there was a negative association between hunger and consumption ($\beta_{10} = -0.003$, $p = 0.019$) when thoughts about snacks and craving intensity were simultaneous predictors for

**Table 4**
Coefficients (β) with robust standard errors (SE) and p-values of the mixed model with craving intensity and type of snacks as predictors at Level 1 and trait food craving as a predictor at Level 2 on thoughts about snacks.

| Model | Coefficient ß (*SE*) | *p* |
|---|---|---|
| **Thoughts about Snacks with Level 1 predictors** [a] | | |
| Intercept ($\beta_{00}$) | 1.72 (0.13) | **<0.001** |
| Craving intensity ($\beta_{10}$) | 0.02 (0.004) | **<0.001** |
| Type of snacks ($\beta_{20}$) | 0.34 (0.11) | **0.004** |
| **Thoughts about Snacks with Level 1 and Level 2 predictors** [b] | | |
| **Level 1** | | |
| Intercept ($\beta_{00}$) | 1.72 (0.13) | **<0.001** |
| Craving intensity ($\beta_{10}$) | 0.02 (0.003) | **<0.001** |
| Type of snacks ($\beta_{20}$) | 0.33 (0.11) | **0.004** |
| **Level 2** | | |
| Trait food craving ($\beta_{01}$) | 0.01 (0.01) | 0.180 |
| **Cross-level interactions** | | |
| Trait food craving × craving intensity ($\beta_{11}$) | 0.001 (0.0003) | **0.028** |
| Trait food craving × type of snacks ($\beta_{21}$) | 0.02 (0.01) | **0.035** |

*Notes. P*-values < 0.050 are printed in boldface.
[a] Level 1 model equation: thoughts about $snacks_{ij} = \pi_{0j} + \pi_{1j}$ (craving intensity) + $\pi_{2j}$ (type of snacks) + $e_{ij}$; Level 2 model equations: $\pi_{0j} = \beta_{00} + r_{0j}$; $\pi_{1j} = \beta_{10} + r_{1j}$; $\pi_{2j} = \beta_{20} + r_{2j}$.
[b] Level 1 model equation: thoughts about $snacks_{ij} = \pi_{0j} + \pi_{1j}$ (craving intensity) + $\pi_{2j}$ (type of snacks) + $e_{ij}$; Level 2 model equations: $\pi_{0j} = \beta_{00} + \beta_{01}$ (trait food craving) + $r_{0j}$; $\pi_{1j} = \beta_{00} + \beta_{11}$ (trait food craving) + $r_{1j}$; $\pi_{2j} = \beta_{20} + \beta_{21}$ (trait food craving) + $r_{2j}$.

consumption (all *ps* $\leq$ 0.001). Importantly, trait food craving was not related to hunger in general ($\beta_{01} = -0.01$, $p = 0.962$) and there were no cross-level interactions of trait food craving and hunger (all *ps* $\geq$ 0.293). Effects remained significant for the other cross-level interactions (i.e., trait food craving with type of snack and craving intensity; all *ps* < 0.037).

## 4. Discussion

The present study aimed at characterizing food craving experiences by means of seven days of EMA with five daily signals. In addition to examining these experiences in terms of content and frequency, their cognitive and behavioral correlates were of interest as was the potentiating role of trait food craving.

Our first aim of characterizing frequency and specificity of food craving experiences investigated whether previous findings derived from laboratory or questionnaire-based studies actually reflect individuals' behavior in everyday life. Such previous studies reported that chocolate next to other high-calorie snack foods are most frequently desired in Western societies (e.g., Nicholls & Hulbert-Williams, 2013; Rozin et al., 1991; Weingarten & Elston, 1990). Indeed, our data confirmed this finding: 86% of all reported snack foods were high in sugar and/or fat and chocolate-containing foods were the most frequently reported high-calorie snack (26% of all prompts), which was consistently reported across measures (i.e., self-report prior to the study and EMA).

In line with the hypotheses under the second aim, snack-related thoughts, state cravings, and consumption were all significantly interrelated and co-occurred in the same time interval within individuals. However, this does not imply that all thoughts or cravings necessarily lead to consumption. While the elaborated intrusion theory of desire proposes that thoughts about tempting foods are essential for the emergence of cravings (Kavanagh et al., 2005) and, thus, making causality between these thoughts and cravings likely, several processes may moderate whether snack-related thoughts and/or cravings result in snack consumption. For example, in a "hot" motivational state (e.g., during experiences of hunger or exposure to attractive foods), food cravings may influence consumption more directly than in a "cold" motivational state (Appelhans et al., 2016; Hofmann & Van Dillen, 2012), where self-control likely prevents consumption.

Our third aim pertained to the question whether high trait food cravers are more susceptible to snack-related thoughts, cravings, or consumption. Unexpectedly, there were no direct effects of trait food craving on momentary craving intensity or snack consumption. This contrasts with laboratory studies in which high trait food cravers reported higher craving intensity in response to food cues than low trait food cravers (e.g., Hallam et al., 2016; Meule, Skirde, et al., 2012) and further points to context effects (laboratory vs. daily life). Thus, while food picture viewing in the laboratory triggers state cravings for food quite consistently in trait food cravers, such correspondence of state and trait might be contingent on food cue exposure (e.g., sight or smell). In the natural environment, by contrast, exposure to food cues might vary considerably across

**Table 5**
Coefficients (β) with robust standard errors (SE) and p-values of the mixed model with thoughts about snacks and craving intensity as predictors at Level 1 and trait food craving as a predictor at Level 2 on consumption of snacks.

| Model | Coefficient ß (*SE*) | *p* |
|---|---|---|
| **Consumption of snacks with Level 1 predictors** [a] | | |
| Thoughts about snacks ($\beta_{10}$) | 0.19 (0.06) | **<0.001** |
| Craving intensity ($\beta_{20}$) | 0.20 (0.03) | **<0.001** |
| Thoughts about snacks × craving intensity ($\beta_{30}$) | 0.07 (0.04) | 0.051 |
| **Consumption of snacks with Level 1 and Level 2 predictors** [b] | | |
| **Level 1** | | |
| Thoughts about snacks ($\beta_{10}$) | 0.19 (0.05) | **<0.001** |
| Craving intensity ($\beta_{20}$) | 0.19 (0.04) | **<0.001** |
| Thoughts about snacks × craving intensity ($\beta_{30}$) | 0.07 (0.04) | 0.076 |
| **Level 2** | | |
| Trait food craving ($\beta_{01}$) | 0.003 (0.01) | 0.548 |
| **Cross-level interactions** | | |
| Trait food craving × thoughts about snacks ($\beta_{11}$) | 0.003 (0.004) | 0.520 |
| Trait food craving × craving intensity ($\beta_{21}$) | 0.01 (0.003) | **0.040** |
| Trait food craving × thoughts about snacks × craving intensity ($\beta_{31}$) | 0.001 (0.003) | 0.567 |

Notes. P-values < 0.050 are printed in boldface. Predictors at Level 1 were z-standardized within each participant before calculating the product term. Intercept of both model equations a,b: ß00 = 0.97(0.05), p < 0.001.
[a] Level 1 equation: consumption of $snacks_{ij} = \pi_{0j} + \pi_{1j}$ (thoughts about snacks) + $\pi_{2j}$ (craving intensity) + $\pi_{3j}$ (thoughts about snacks × craving intensity) + $e_{ij}$; Level 2 equations: $\pi_{0j} = \beta_{00} + r_{0j}$; $\pi_{1j} = \beta_{10} + r_{1j}$; $\pi_{2j} = \beta_{20} + r_{2j}$; $\pi_{3j} = \beta_{30} + e_{3j}$.
[b] Level 1 equation: consumption of $snacks_{ij} = \pi_{0j} + \pi_{1j}$ (thoughts about snacks) + $\pi_{2j}$ (craving intensity) + $\pi_{3j}$ (thoughts about snacks × craving intensity) + $e_{ij}$; Level 2 equations: $\pi_{0j} = \beta_{00} + \beta_{01}$ (trait food craving) + $r_{0j}$; $\pi_{1j} = \beta_{00} + \beta_{11}$ (trait food craving) + $r_{1j}$; $\pi_{2j} = \beta_{20} + \beta_{21}$ (trait food craving) + $r_{2j}$; $\pi_{3j} = \beta_{30} + \beta_{31}$ (trait food craving) + $r_{3j}$.

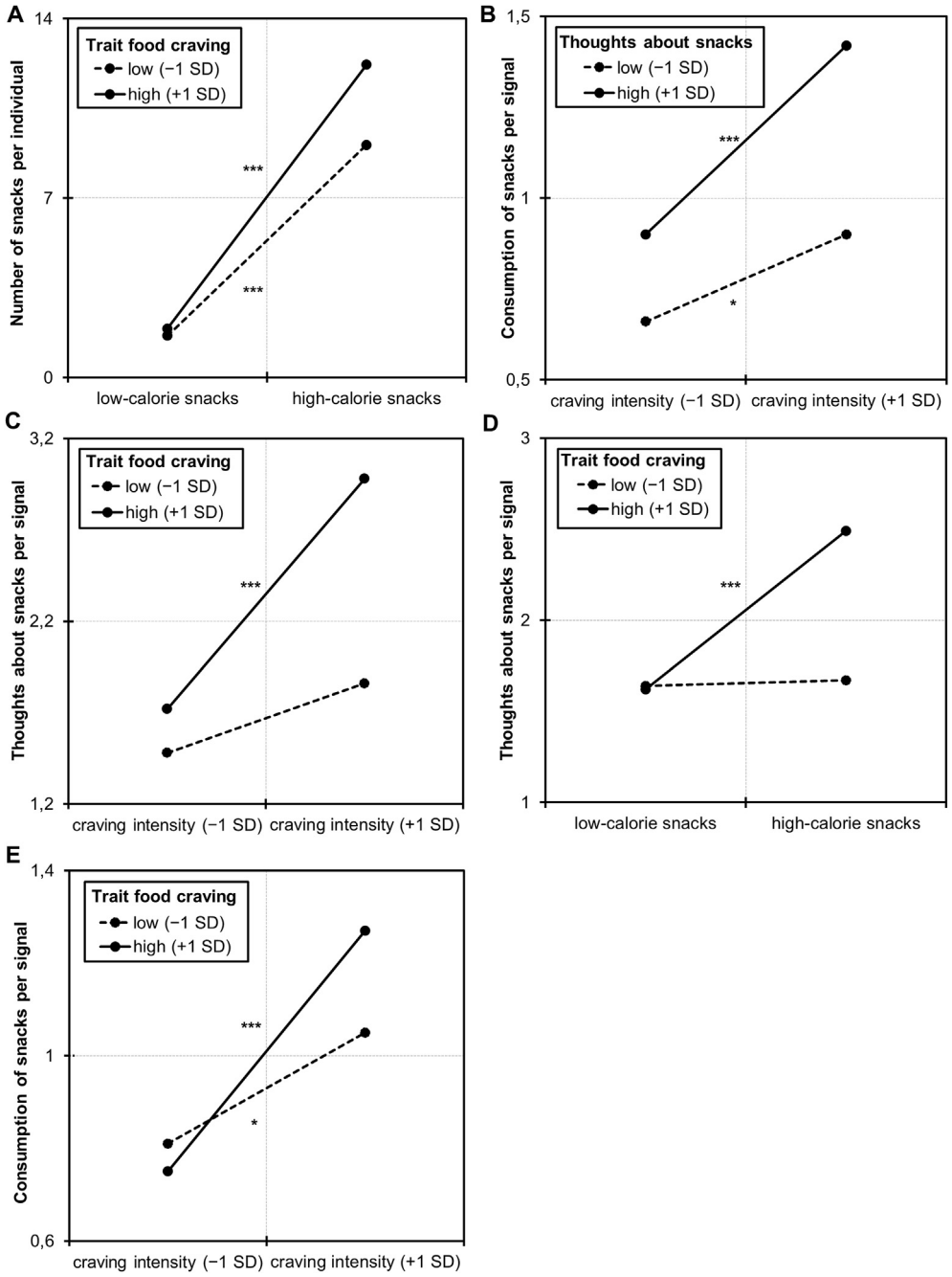


**Fig. 2.** (A) Simple slopes probing the interaction between type of snacks and trait food craving when predicting the number of snacks reported. Individuals with low FCQ-T-r scores, $\beta = 7.45$, $SE = 0.94$, $t_{(59)} = 7.89$, $p < 0.001$, and individuals with high FCQ-T-r scores, $\beta = 10.8$, $SE = 0.98$, $t_{(59)} = 11.0$, $p < 0.001$, reported more high-calorie snacks than low-calorie snacks, with this effect being slightly more pronounced in individuals with high FCQ-T-r scores (marginally significant cross-level interaction: $\beta_{11} = 1.67$, $p = 0.055$). (B) Simple slopes probing the interaction between craving intensity and thoughts about snacks when predicting consumption of snacks per signal. Higher craving intensity was particularly associated with more consumption of snacks when participants reported a high number of thoughts about snacks, $\beta = 0.27$, $SE = 0.05$, $t_{(59)} = 4.85$, $p < 0.001$, whereas this relationship was attenuated when participants reported a small number of thoughts about snacks, $\beta = 0.12$, $SE = 0.05$, $t_{(59)} = 2.46$, $p = 0.017$. (C) Simple slopes probing the interaction between craving intensity and trait food craving when predicting thoughts about snacks per signal. Higher craving intensity was associated with more thoughts about snacks in individuals with high FCQ-T-r scores, $\beta = 0.63$, $SE = 0.10$, $t_{(59)} = 6.52$, $p < 0.001$, but not in individuals with low FCQ-T-r scores, $\beta = 0.19$, $SE = 0.10$, $t_{(59)} = 1.89$, $p = 0.063$. (D) Simple slopes probing the interaction between type of snacks and trait food craving when predicting thoughts about snacks per signal. Individuals with high FCQ-T-r scores reported significantly more thoughts about high-calorie snacks than low-calorie snacks, $\beta = 0.87$, $SE = 0.22$, $t_{(59)} = 4.03$, $p < 0.001$, whereas no difference was found in individuals with low FCQ-T-r scores, $\beta = 0.03$, $SE = 0.22$, $t_{(59)} = 0.14$, $p = 0.893$. (E) Simple slopes probing the interaction between craving intensity and trait food craving when predicting consumption of snacks per signal. Higher craving intensity was associated with more consumption of snacks in individuals with high FCQ-T-r scores, $\beta = 0.26$, $SE = 0.05$, $t_{(59)} = 5.18$, $p < 0.001$, whereas this relationship was attenuated in individuals with low FCQ-T-r scores, $\beta = 0.12$, $SE = 0.05$, $t_{(59)} = 2.27$, $p = 0.027$. *** $p < 0.001$, * $p < 0.050$.

situations and daytimes (Boswell & Kober, 2016; Cepeda-Benito, Fernandez, & Moreno, 2003), showing that state and trait may be separable to some extent. Also, it has been reported that, although trait food craving and momentary craving intensity are related to each other, this relationship is rather small (Cepeda-Benito et al., 2000; Meule, Hermann, et al., 2014; Meule, Lutz, Vögele, & Kübler, 2012). In sum, the findings indicate that high trait food cravers do not have a chronic and persistently elevated level of state craving but rather show an increase in state cravings in certain situations.

In contrast, trait food craving was associated with more frequent thoughts about snack foods. This corresponds well with the respective items of the FCQ-T-r (e.g., "I find myself preoccupied with food"; Cepeda-Benito et al., 2000; Meule, Hermann, et al., 2014) and provides ecological validity for the instrument. Furthermore, regarding type of snack food, high trait food cravers thought more frequently about high-calorie snacks than low-calorie snacks, whereas no such differences were found in low trait food cravers. Thus, both frequency and specificity of food craving experiences can be predicted by trait food craving in the natural environment, revealing a generally greater elaboration of high-calorie foods in trait food cravers. Again, there is some correspondence with laboratory work: when state craving was triggered, individuals with high trait food craving showed heightened reactivity in an approach avoidance task (Brockmeyer et al., 2015), implicit measures (Richard et al., in revision), and greater reward-related brain activitation (Miedl et al., submitted; Ulrich et al., 2016).

Although there were no direct effects of trait food craving on craving intensity or snack consumption, trait food craving moderated the relationships between thoughts about snacks and craving intensity as well as between craving intensity and snack consumption. That is, high trait food cravers thought more often about snack foods and consumed more snack foods, particularly when they experienced intense cravings for these foods. Thus, while individuals with low trait food craving may also experience intense state cravings for food, it appears that their consequences differ between high and low trait food cravers. Consequently, intense food cravings in high trait food cravers might represent "hot" motivational states (cf., Appelhans et al., 2016) that go along with both cognitive elaboration and consumption, while being less consequential in low trait food cravers.

Hunger was one of the control variables in the present study that deserves discussion. Hunger was indeed related to more snack-related thoughts, suggesting that food cravings and hunger often co-occur (Gilhooly et al., 2007). However, hunger was negatively related to snack consumption, which is in line with previous research. For instance, snack foods are often consumed as between-meal groceries in the absence of hunger (Cleobury & Tapper, 2014), and state chocolate craving was a better predictor of chocolate consumption than hunger (Meule & Hormes, 2015). Importantly, hunger did neither confound the relationships between snack-related thoughts, cravings, and consumption nor was there a relationship with trait food craving. Thus, the present investigation may represent a demonstration of the partial independence of craving and hunger experiences (Blechert, Naumann, Schmitz, Herbert, & Tuschen-Caffier, 2014; Pelchat & Schaefer, 2000; Richard et al., in revision).

### 4.1. Limitations and future directions

The present findings are based on a sample of young, female students, which limits the generalizability to men and individuals with higher age, higher BMI, or lower education. As food cravings are thought to be more common in females (Hormes, Orloff, & Timko, 2014) and young adults (Pelchat, 1997), future studies should replicate findings in samples with broader range in variables such as age, BMI, or education. Previous research also suggests that individuals can successfully withhold consumption in the presence of food cravings (Hill, 2007). Hence, future studies should aim at investigating a more comprehensive set of environmental (e.g., availability of food) and individual characteristics to gain insight into when food craving experiences result in snack consumption and when this is not the case. Also, the current investigation does not inform about all types of snacking behavior (which also includes mindless snacking; Wansink & Sobal, 2007), but only about snack consumption that can be consciously recalled. However, retrospective recall may be biased even for a short period of three hours (as used here). A combination of event-contingent sampling (i.e., immediate report of each snack) and signal-contingent sampling might help in estimating the size of this bias (through comparison of concurrent and retrospective reports), while a complete account of snacking prevalence likely requires more continuous measurements (e.g., chewing- or swallowing-detection; Papapanagiotou et al., 2016).

## 5. Conclusions

To conclude, snack-related thoughts, cravings and consumption are highly interrelated in daily life. This is particularly true for trait food cravers who think more often about high-calorie snack foods and consume more snack foods in response to intense cravings. To date, interindividual differences in food craving experiences have received relatively little attention in interventions that target regulation of thoughts about tempting foods (e.g., May, Kavanagh, & Andrade, 2015). The present findings give evidence for ecological validity as well as practical relevance of the concept of trait food craving outside the laboratory.

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## Appendix

Model equation for the prediction of thoughts about snacks by craving intensity (modeled at Level 1) and by trait food craving (modeled at Level 2). Similar models were used for the prediction of consumption of snacks by thoughts about snacks and craving intensity.

*Level 1 (occasions):*

$$\text{Thoughts about snacks}_{ij} = \pi_{0j} + \pi_{1j}\,(\text{craving intensity}_{ij}) + e_{ij}$$

*Level 2 (participants):*

$$\pi_{0j} = \beta_{00} + \beta_{01}\,(\text{trait food craving}) + r_{0j}$$
$$\pi_{1j} = \beta_{10} + \beta_{11}\,(\text{trait food craving}) + r_{1j}$$

The outcome (participant's *j* level of thoughts about snacks) was displayed as a function of an intercept ($\pi_{0j}$) and a slope ($\pi_{1j}$) at Level 1. This shows the effect of craving intensity$_{ij}$ (participant's *j* level of craving intensity). The intercept $\pi_{0j}$ represents participant's *j* level of thoughts about snacks at an average level of craving intensity. At

Level 2, the intercepts ($\beta_{00}$) and ($\beta_{10}$) show the mean level of thoughts about snacks and the mean effect of craving intensity, when trait food craving is on an average level due to grand-mean centering of trait food craving. The regression weights (Level 2 slopes) represent associations between the Level 2 predictor trait food craving and thoughts about snacks ($\beta_{10}$) and craving intensity ($\beta_{11}$), respectively.

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