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The Effects of Cognitive Load on Craving Triggered by Food Cues in External Eaters

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This study examined the effects of cognitive load on attentional bias toward food cues in external eaters (EEs) through an eye-movement analysis. As EEs are easily driven to eat upon exposure to food cues, the present study examined the effects of cognitive load on the response toward food cues in EEs based on the elaborated intrusion theory. A total of 65 undergraduates who have high ($n = 33$) or low ($n = 32$) levels of external eating were assigned to either high or low cognitive load conditions and performed a cognitive load task. While they performed the load task, their implicit craving was measured with an eye-tracking device to examine the levels of attentional bias toward food cues during the task. After the task was completed, explicit craving was investigated through a questionnaire. The results showed that high EEs under a high cognitive load condition showed lower implicit craving than under a low load condition while their explicit craving did not differ. This study suggests that cognitive load that induces cognitive distraction may lower implicit craving in high EEs.

Keywords: external eating, cognitive load, the elaborated intrusion theory, visuo-spatial working memory, eye-tracking device

As our modern lifestyle has changed into an obesogenic environment, external eating which is described as a tendency to eat with the exposure of food cues has been demonstrated to be a vulnerability factor for overeating and obesity (Hou et al., 2011). As noted in previous studies, external eaters (EE) who have an increased tendency to eat when exposed to external cues (e.g., sight or smell of food) showed selective attention to food stimuli (Hou et al., 2011; Nijs, Franken, & Muris, 2009) and poorer ability to adjust impulsive responses toward food cues (Hou et al., 2011). This external eating style might function as a vulnerability factor to overeating or obese-related problems, as palatable food is abundant and easily accessible in this current obesogenic environment (Nijs et al., 2009). For this reason, intervening in the external eating style might be essential to prevent and relieve risks from problems regarding impulsive eating.

The external eating tendency could be explained by the Elaborated Intrusion Theory of Desire (May, Andrade, Panabokke, & Kavanagh, 2004; May, Kavanagh, & Andrade, 2015). According to the theory, exposure to food cues provokes intrusive thoughts, which are spontaneous. They can be a schematic thought, a verbal thought, or an image about food (Andrade, May, & Kavanagh, 2012). In this process, there is an automatic association by experience that does not require conscious control. Through the process of elaboration, this intrusive thought can become craving. Elaboration is conducted by sensory imagery, which is an ability to mentally simulate the sound, smell, taste, and feel of an experience and exercises visuo-spatial working memory (VSWM) resources (Andrade et al., 2012). The Elaborated Intrusion Theory of Desire highlights the role of VSWM, which is necessary in elaboration of food images. As more elaborating of food images with VSWM occurs, the higher proba-

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bility that food craving will spring up. In other words, by reducing the VSWM resource, this elaboration could be prevented from becoming craving. Therefore, according to the theory, VSWM plays the most important role in the elaboration of the desire process.

The reducing effect of cognitive load on craving for desire inducing stimuli has been controversial. Some studies suggested that cognitive load could heighten cravings for addictive stimuli, as the cognitive load might deplete cognitive resources that are needed for controlling impulsive behaviors. For instance, Ward & Mann (2000) found that the cognitive load may change dieters' eating style to disinhibiting eating behavior, since cognitive load depletes cognitive resources which are to manage the effects of temptations on behaviors. This phenomenon was continuously suggested by other research (e.g., Baumeister, Bratslavsky, Muraven, & Tice, 1998; Vohs & Heatherton, 2000), which commonly highlighted the depletion of resources for self-regulation. However, these studies' tasks exhausted all cognitive resources, and did not focus on depleting VSWM resource. It led to an ego-depletion state which negatively influence people's ability to control their desire.

Contrary to previous perspective, it was revealed that cognitive load focusing on VSWM, not ego-depletion, had an effect on reducing food craving (Skorka-Brown, Andrade, & May, 2014; Tiggemann, Kemps, & Parnell, 2010). Recent studies insist that cognitive load could lower craving for addictive stimuli and they tried to interrupt the process of desire elaboration with experimental tasks which were for depleting the VSWM capacity. The ironic effects of cognitive load may be explained away with the kinds of resource that the cognitive load depletes. Although several studies discovered the ego-depletion phenomenon that standing for the state of being exhausted with high cognitive load (Vohs & Heatherton, 2000; Ward & Mann, 2002), cognitive load that only depleted VSWM resources for preventing elaboration of imagery may reduce cravings for addictive stimuli, rather than heightening them (May et al., 2015; Sharbanee, Stritzke, Jamalludin, & Wiers, 2014; Van Dillen, Papies, & Hofmann, 2013). Consequently, as EEs have high reactivity to food cues (Burton, Smit, & Lightowler, 2007), they have intrusive thoughts when encountering food-related stimuli. In order to reduce their craving and emotional eating behaviors, increasing cognitive load on VSWM could be effective.

A mental arithmetic task can be used as a tactic to add cognitive load on VSWM. As a mental arithmetic task, especially a subtraction task, it requires a great amount of VSWM resources (Chong, et al., 2010; Imbo, & LeFevre, 2010; Lee & Kang, 2002), and it may induce a cognitive load on VSWM, which should be followed by interruption of cognitive elaboration toward food cues because of limited working memory resources. This is because the subtraction task may hold the representations of numbers in VSWM (Lee & Kang, 2002). Unlike addition or multiplication that may require access to the verbal working memory for the efficiency of calculation, subtraction generally relies on the capacity of VSWM capacity only (Andres, Michaux, & Pesenti, 2012; Lee & Kang, 2002). Therefore, it is possible that the cognitive load on VSWM resources would reduce craving toward food cues in EEs who are sensitive to the salience of food cues.

To investigate the effect of cognitive load on craving for addictive stimuli, it would be necessary to research both explicit and implicit aspects. Craving for addictive stimuli could be divided into explicit and implicit aspects according to the dual-process model (Wiers & Stacy, 2006). This model suggests that social behavior is a compound of reflective process which is slow, conscious, but also an explicit and impulsive process which is fast and automatic (Larsen, Engels, Wiers, Granic, & Spijkerman, 2012). Because implicit craving, the automatic response to addictive stimuli, is uncontrollable, it could show craving without the influence of one's intention. Accordingly, examining the craving in the aspect of explicit and implicit is required. It is important to note that attentional bias shows implicit craving toward food or addictive cues (Sayette, 2016). The attentional bias can be measured in terms of eye movement, which is automatic physiological response, by using eye-tracking device. That is, interrupting the function of VSWM might disrupt the tendency of EE's attentional bias toward food cues because of the limited capacity of working memory (Pessoa & Adolphs, 2010). Therefore, measuring attentional bias would reveal the effect of cognitive load on VSWM to implicit craving.

Based on these previous studies, the study aimed to investigate the effects of cognitive load on EEs' attentional bias and levels of craving toward food cues. Since previous studies suggested that cognitive load could reduce attentional bias and level of cravings on food cues (Van Dillen et al., 2013), mental arithmetic, which is proved to induce cognitive load on visual working memory may also attenuate attentional bias and the level of cravings on food stimuli. Therefore, this study examined whether the cognitive load would reduce attentional bias and craving toward food cues in high EEs.

Methods

Participants

Prior to the experiment, as a screening measure for external eater, a total of 950 undergraduates completed the Korean version of the Dutch Eating Behavior Questionnaire (DEBQ; Van Strien, Frijters, Bergers, & Defares, 1986; Kim, Lee, & Kim, 1996). Participants were recruited through the Internet bulletin board of several universities in Seoul, Korea. Based on previous studies (Van Strien, Herman, Anschutz, Engels, & de Weerth, 2012), norm group of undergraduates who showed extreme end scores of the external eating subscale of DEBQ were selected as participants. Therefore, participants in the 20th percentile of the external eating score (below 2.7) and 80th percentiles (above 3.7) were divided into (a) high EE ($n=41$), (b) low EE ($n=40$). As some of the participants showed irregular patterns regarding food attentional bias indexes ($n=9$; above or below 1.5sd; Müller, Baumeister, Dziobek, Banaschewski, & Poustka, 2016), or had known the purpose of the experiment (showed irregular pattern on food attentional bias indexes at the same time; $n=4$), or taking medication to lower body fat ($n=1$), or confessed to the inaccuracy of the self-reported external eating score because the time of measure was too long ago (showed irregular pattern on food attentional bias indexes at the same time; $n=2$), the statistical analysis was conducted on the remaining 65 participants (high EE = 33, low EE = 32).

Materials

The Korean version of Dutch Eating Behavior Questionnaire

The levels of external eating were measured with DEBQ (Van Strien et al., 1986; Kim et al., 1996). This questionnaire has 33 items in total, and consists of 3 scales (restraint eating, emotional eating, external eating) with 10 items, 13 items, and 10 items in each. In this study, the external eating scale was used to screen out 20th and 80th levels of EEs. The Cronbach α of this questionnaire was .93 (Kim et al., 1996).

Binge Eating Scale (BES)

In order to understand participants' characteristics, the Binge Eating Scale was used in measuring the severity of binge eating with indexes of behavior, feelings, and cognition (Gormally, Black, Daston, & Rardin, 1982). This scale consists of 16 items with ranges from 0 to 3, and higher score means severe levels of binge eating problems. The Cronbach α of validated BES was .84 (Park & Park, 2008).

Mathematics Anxiety Scale

As mental arithmetic equations were presented during the cognitive load task, the levels of math anxiety were measured with the Mathematics Anxiety Scale (MAS; Fennema & Sherman, 1976) in the case of covariate analysis. This questionnaire consists of 12 items with 5-point-likert type scale, and higher score means higher levels of math anxiety. The Cronbach α of Korean version MAS was .93 (Lee, 2012).

Hunger scale

The levels of hunger were measured before the experiment began, as hunger could affect the task performance or levels of attentional bias toward food cues (Forestell, Lau, Gyurovski, Dickter, & Haque, 2012). All the participants rated levels of hunger with Visual Analogue Scale (VAS), which consists of "Not hungry at all" to "Extremely hungry" (Chaput, Gilbert, Gregersen, Pedersen, & Sjödin, 2010; Grand, 1968).

Self-reported craving

The levels of craving were measured after the cognitive load task was finished. All participants reported subjective craving with 9-point Likert-type scale in four questions (e.g., At this moment, how much do you desire to eat?; how much appetite do you feel?; how much do you feel the urge to eat?; how much do you feel like snacking) ranging from 1 (not at all) to 9 (very much) (Van Dillen et al., 2013).

Body Mass Index

Participants' descriptive characteristic was measured by Body Mass Index (BMI; kg/m^2) with self-reported questionnaire. All participants answered questions about their height and weight.

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Confessing awareness of the deception in the experiment.

All participants reported whether they had known the original purpose of the study at the end of the experiment, in order to exclude the possibility of deliberately controlling their eye-movements when they were gazing at the pairs of food and neutral stimuli. Participants were recommended to write down and talk about the purpose of the experiment or whether they had known the purpose of the deception.

Cognitive Load Task

In order to measure the attentional bias toward food cues during the cognitive load phase, we developed a task to induce cognitive load during the eye-tracking period. In this cognitive load task, participants were presented with a simple version of arithmetic equations during the eye-tracking measure period. Before taking part in the experiment, in order to inhibit the possibility to control their eyes by catching the original purpose of the experiment, all participants received deceptive instruction that the purpose of the experiment is to find the relationship between accuracy of mental arithmetic and eye-movement. In the eye-tracking phase, the sequence of events was as follows. A fixation dot was presented for 1,000 ms and was replaced sequentially by the first number, the minus sign (-), and then the second number. Each of the elements was presented for 400 ms. Then the food and neutral picture pair appeared for 3,000 ms, followed by a blank screen for 2000 ms. The participants took the instruction that gazing at the monitor while memorizing each number and operation, and after that, calculating arithmetic equations while keeping fixed on the pairs of stimuli. They reported the answer of mental arithmetic vocally while the blank screen was presented. In order to control the direction of eye-movement depending on the magnitude of arithmetic equations (Masson & Pesenti, 2014), food stimuli appeared on either the right or the left side of the screen, in a randomized and counterbalanced order. The number of pairs were determined as 36 trials with the number of arithmetic equations stimuli as in a previous study (Masson & Pesenti, 2014). To measure the attentional bias toward food stimuli, time to first fixation and fixation duration were investigated. Each factor represents their first engagement with food stimuli and the duration of time spent gazing at the food stimuli. Attentional bias was measured with an eye tracker device.

This task was designed for the purpose of inducing a cognitive load while measuring attentional bias toward food cues. The overall procedures of the task, regarding the time of presentation showing numbers and operand, and arithmetic equations stimuli were derived from the study of mental arithmetic (Masson & Pesenti, 2014). According to the previous study, a mental arithmetic task, especially subtraction, put heavy load on VSWM resource. In addition, subtractions with carrying or borrowing numbers induce higher cognitive load comparing subtractions without it. Therefore, in this study, the high cognitive load condition was set with subtraction with carrying or borrowing numbers and the low cognitive load condition was set with subtraction without it. The food and neutral stimuli were picked up from 'Food-pics' data base (Blechert, Meule, Busch, & Ohla, 2014). Also, this study rated the picture's 'relevance with food' 'valence', and 'arousal' through 31 people who had nothing to do with this experiment. For food stimuli, high calorie foods such as French fries, cookies, sweets, doughnuts, slice of bread, ice cream, chocolate, chicken, cake, fried foods, pasta, pizza and hamburger were used. For neutral stimuli, non-food objects which were matched with food stimuli in color, shape, and complexity were used. The overall procedure of the task is illustrated in Figure 1.

Apparatus

Participants' eye movements were tracked with an eye tracker device (iView XTM Red - IV Eye Tracking System, Sensomotoric Instruments GmbH, Berlin, Germany). The participants were seated 70 cm in front of a 22 inch screen monitor. The eye tracker was interfaced with a desktop computer monitor which recorded the data. Eye movement was recorded 60 times per second (i.e., 60Hz).

Procedure

The institutional review board of the Chung-Ang University approved the study, written informed consent was obtained from all participants. After screening out 81 participants from 950 undergraduates with the criterion of 20th and 80th on external eating, all participants were invited to the laboratory and presented with informed consents. The participants were randomly assigned to high or low cognitive load conditions. Then, participants complet-

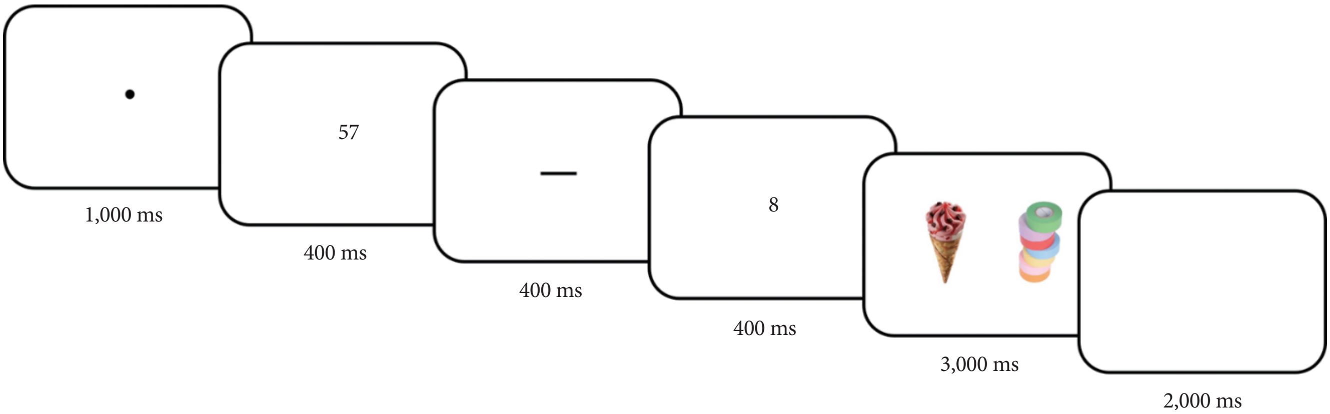

Figure 1. *The cognitive load task.*

ed the BES, Mathematics Anxiety Scale, Hunger scale, and BMI questionnaires. After completing the questionnaires, each participant was required to sit at a desk in front of a computer monitor and was asked to keep a distance of 68–70 cm from the monitor. During eye tracking period, they conducted the cognitive load task for about 15 minutes (6 practice trials, 36 experiment trials). The participants completed the Craving questionnaire after the cognitive load task. Finally, they were debriefed. They were asked whether there was any discomfort or difficulty during the process and told not to share the purpose of this experiment with anyone else. The total procedure took 30 minutes and participants were provided a reward of U.S $4.

Data Analysis

To analyze the difference between groups and conditions, 2 (Group: High EEs vs. Low EEs) × 2 (Conditions: High cognitive load vs. Low cognitive load) univariate ANOVA was conducted on the eye-tracking data and self-reported craving. The levels of attentional bias were calculated by subtracting values of neutral stimuli from values of food stimuli, in order to find out the gazing bias toward food cues compared with neutral stimuli. The positive value implies that the participant gazed at food stimuli more, whereas the negative value suggests that the participant gazed at the stimuli less. For the detailed analysis, a simple main effect procedure was carried out as a post-hoc analysis. SPSS 25.0 for Windows was utilized in the data analysis.

Results

Descriptive Statistics

Table 1 shows the demographic characteristics of the participants analyzed in the present study. The mean age (F[3, 61] = 0.408, *n.s*), BMI (F[3, 61] = 0.319, *n.s*), hunger (F[3, 61] = 0.876, *n.s*), and math anxiety (F[3, 61] = 1.733, *n.s*) were not significantly different between the groups. However, the proportion of sex was significantly different by the groups (χ^2[3] = .393, $p < .05$). Difference in sex ratio by groups could present epidemiology of eating disorders indicating that the female sex is associated with a high eating disorder prevalence and incidence (Mitchison & Hay, 2014).

According to the selection criteria, there was significant effects between groups for external eating (F[3, 61] = 165.070, $p < .01$, η^2 = .890). In addition, in the analysis of clinical measures, there were significant effects between the groups for BES (F[3, 61] = 13.931, $p < .05$, η^2 = .407). It should be noted that the high EE group had a significantly higher number of problems related to eating than low EE.

Attentional Bias

In order to examine the levels of attentional bias toward food cues, two-way ANOVA was conducted on the eye-tracking data. The pattern of attentional bias was measured with indexes of time to first fixation and fixation duration. Table 2 shows the attentional bias score by groups. The attentional bias was calculated by measured values toward food stimuli - measured values toward neutral stimuli (Gable & Harmon-Jones, 2010; Kakoschke, Kemps, & Tigge-

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Table 1. *External Eating Score and Demographic Data of Groups*

	Low External Eaters		High External Eaters		Test Statistics (F/χ^2)
	Low cognitive load ($N=17$)	High cognitive load ($N=15$)	Low cognitive load ($N=17$)	High cognitive load ($N=16$)	
Sex (*N* [%] female)	10 (58.8)	7 (46.7)	15 (88.2)	14 (87.5)	.393*
Age	21.41 (2.03)	21.20 (2.24)	20.65 (1.84)	21.06 (2.21)	.408
BMI	20.74 (2.69)	21.42 (2.33)	21.72 (3.61)	21.03 (3.91)	.319
BES	24.82 (4.63)	24.73 (5.55)	34.35(5.49)	33.75 (7.26)	13.931*
DEBQ					
External eating	2.29 (.28)	2.40 (.29)	4.04 (.34)	4.04 (.31)	165.070*
Hunger	29.00 (28.59)	44.33 (32.54)	41.41 (27.94)	33.56 (32.28)	.876
Math anxiety	31.29 (9.21)	30.33 (7.43)	36.88 (9.36)	32.44 (9.45)	1.733

Mean (standard deviation).
Note. BMI = Body Mass Index; BES = Binge Eating Scale; DEBQ = The Korean version of Dutch Eating Behavior Questionnaire.
*$p<.05$.

Table 2. *Attentional Bias Score of Groups*

	Low External Eaters		High External Eaters	
	Low cognitive load ($N=17$)	High cognitive load ($N=15$)	Low cognitive load ($N=17$)	High cognitive load ($N=16$)
Time to first fixation index	11.79 (40.17)	41.16 (88.08)	19.93 (41.97)	10.63 (50.20)
Food (ms)	263.24 (60.24)	262.47 (98.68)	160.08 (59.42)	267.94 (74.30)
Neutral (ms)	251.45 (66.36)	221.31 (49.14)	240.15 (47.60)	257.31 (79.43)
Fixation duration index	2.80 (32.18)	18.32 (40.71)	16.54 (30.92)	-4.99 (41.61)
Food (ms)	253.24 (62.27)	258.31 (77.23)	257.06 (58.18)	250.30 (58.77)
Neutral (ms)	250.44 (59.89)	240.00 (58.88)	240.52 (43.73)	255.29 (81.36)

Mean (standard deviation). The attentional bias scores which include time to first fixation index and fixation duration index were calculated by subtracting values of neutral stimuli from values of food stimuli.

mann, 2015). Two-way ANOVA with the cognitive load (High, Low) as a within-subject factor and external eating (High, Low) as a between-subject factor was conducted to examine levels of attentional bias toward food cues.

Time to first fixation

The time to first fixation was analyzed for initial attention toward stimuli. There was no significant interaction between groups and conditions for the time to first fixation (F[1,61] = 1.843, $p=.180$, $\eta^2=.029$). This could imply that the first engagement toward food stimuli did not differ between the groups and conditions. The main effect of groups on the time to first fixation was conducted to investigate whether there were differences between high EE group and low EE group. There were no significant group differences in time to first fixation (t[63] = 0.711, *n.s.*). To investigate the effect of conditions, *t*-test was conducted. Time to first fixation was not different by condition (t[63] = 0.668, *n.s.*)

Fixation duration

The fixation duration was analyzed for maintenance of attentional bias toward stimuli. The analysis showed significant interaction between groups and conditions for fixation duration (F[1, 61] = 4.185, $p=.045$, $\eta^2=.064$). To conduct post-hoc analysis on differences regarding fixation duration, simple main effect analysis was used to examine the group differences according to the experimental condition. Within the high EE group, the fixation duration in high cognitive load condition was marginally significantly shorter than in low cognitive load condition (F[1, 61] = 3.165, $p=.080$, $\eta^2=.049$). Overall, this means that high EEs who were under the condition of high cognitive load showed reduced attentional bias toward food cues compared those under a to low cognitive load. However, the same effect was not confirmed in low EE group, as no main effect was found with the simple main effect analysis. Figure 2 shows the interaction of external eating and cognitive load on differences in fixation duration. There were no sig-

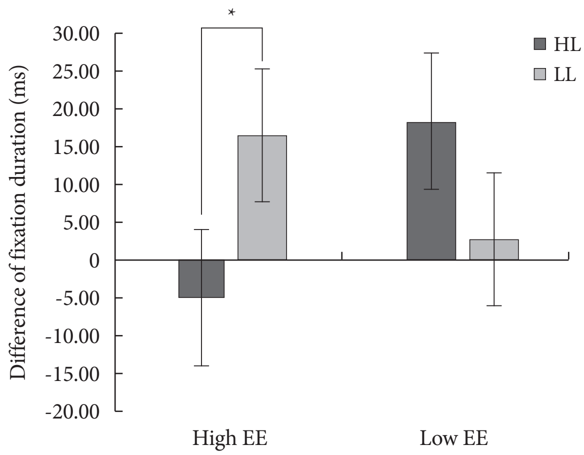

Figure 2. *The difference of fixation duration according to the levels of external eating and cognitive load (value of food stimuli-neutral stimuli).*
Note. EE = External Eating; HL = High Load; LL = Low Load. Error bar = Standard error.
**p = .08.*

nificant group differences in fixation duration (t[63] = 0.431, *n.s.*], which implies that the fixation duration would not be influenced by the levels of external eating. In addition, there was no significant effect between conditions for fixation duration (t[63] = -0.367, *n.s.*], indicating that participants did not show any differences in maintenance of attentional bias between the conditions.

Self-reported craving

Two-way ANOVA was conducted on the levels of craving which was rated with a self-reported questionnaire. The levels of craving were examined with the cognitive load (High, Low) as a within-subject factor and external eating (High, Low) as a between-subject factor. The analysis showed no significant effect on the levels of craving (F[1,61] = 0.960, *n.s.*). The main effects of group on self-reported craving was not significant (t[63] = 1.067, *n.s.*], which means the group characteristics and experimental manipulation was not be shown with self-reported data.

Discussion

The current study aims to examine the effects of cognitive load on VSWM on craving toward food cues among EEs. Cognitive load was used to prevent elaboration of desire which contributes to the formation of craving. The explicit craving toward food cues was not influenced by cognitive load in both groups. However, this study found that the difference of cognitive load impacted on implicit craving in EEs. Attentional bias tends to be decreased in high EEs according to the level of cognitive load.

The major finding of this study is that in fixation durations which is the implicit craving, there was a decrease in attentional bias toward food cues in high EEs under the condition of high cognitive load compared to low cognitive load. This result marginally supports our hypothesis that high levels of cognitive load would reduce attentional bias toward food cues. It is consistent with previous studies that inducing cognitive load on VSWM reduced food cravings and unhealthy snacking in people who showed high sensitivity toward hedonic food cues (Van Dillen & Andrade, 2016). This study showed that high levels of cognitive load tend to reduce attentional bias toward food cues, and the effects of reduction. As attentional bias toward addictive stimuli reflects the implicit craving toward addictive substance or food cues (Sayette, 2016), this tendency that the cognitive load reduces attentional bias may show lower implicit craving toward food cues. Therefore, this study suggests that inducing cognitive load on VSWM might be effective in reducing dysfunctional food craving among people who have a risk for obesity or binge eating disorder.

Another finding of this study is that time to first fixation, which implies the first orienting toward food stimuli, was not different between the groups and conditions. The cognitive load had no influence on reducing implicit craving which was rated as the time to first fixation in both high EE and low EE groups. The result of attentional bias might stand for that the load conditions in both groups would bring about an interruption of maintenance of attention rather than initial orienting for food stimuli. It is assumed that high EEs have lower implicit craving for food under the condition of high load although they were captured at their attention to food stimuli at the first time. In addition, two measurements of attentional bias in this study have different mechanisms that point out that initial orienting is a rapid and automatic process, whereas maintenance of attention is likely to be influenced by motivational variables (Field, Mogg, Zetteler, & Bradley, 2004). Therefore, there is a possibility that the cognitive load's effect on reducing implicit craving has a pattern according to the information processing.

The interesting finding of this study is that there was a discor-

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dance in implicit and explicit craving. Although the decreasing pattern of implicit craving by the high cognitive load was found, the explicit craving was not affected by it. As craving for food is a sensitive issue because it is related to eating and leads to feelings of guilt and shame (Kemps, Tiggemann, Martin, & Elliott, 2013), there is a possibility that the participants reported explicit craving with their intentions. Furthermore, although in the prior studies, an attentional bias for relevant stimuli led to craving, positive correlation between attentional bias and craving was found only in overweight, not in normal weight (Werthmann et al., 2011). It is assumed that this result might be derived because participants in both low EE group and high EE group who have an average weight according to the BMI score. As attentional bias has a positive relation with food intake (Nijs, Muris, Euser, & Franken, 2010, Werthmann et al, 2011), a reducing pattern only in implicit craving has the possibility to have an effect on food intake although the explicit craving was not changed. In a future study, the effect of cognitive load in reducing implicit and explicit craving in EEs who are overweight/obese should be investigated. Also, it suggests that the change of food intake caused by high cognitive load should be measured in the next study to broaden this result.

In order for the results of the present study to be convincing, several considerations should be discussed. First, the current study examined the reducing effect of cognitive load by analyzing craving in the condition of high load and low load, and not comparing craving on prior and post task. According to previous studies, there is a potential practice effect when assessing attentional bias (Heeren, Philippot, & Koster, 2015; MacLeod, Rutherford, Campbell, Ebsworthy, & Holker, 2002). Thus, investigating the decreasing effect of cognitive load on craving presuming low load condition as a baseline might be beneficial. In addition, the explicit craving was measured once after the cognitive load task, while the implicit craving was measured repeatedly. Although the influence of cognitive load on attentional bias was investigated according to the previous study (Masson & Pesenti, 2014), it would be necessary to measure both explicit and implicit cravings after the task to compare the effect of cognitive load in a further study. Second, validation of cognitive load task used in this study needs to be considered. Although mental arithmetic which was used in this study as a cognitive load is related with VSWM (Lee & Kang, 2002), it might induce emotional stress or ego-depletion (Witcomb, 2005). Emotional stress and ego-depletion can lead to disinhibition of eating because of a limited capacity for self-regulation. Meanwhile, the accuracy of responses during the cognitive load task should be considered to investigate the influence of cognitive load task on attentional bias toward food stimuli. The analysis should be conducted on a correct trial to reveal the effect of cognitive load. Also, the response time should be measured to check if the task depleted the participant's VSWM resource, in case the capacity of VSWM differs on a personal level. Therefore, the accuracy and response time of each trial should be measured in a future study. Lastly, there is a possibility that the questionnaires about food could increase the craving toward food because the questionnaires could make the participants think about their state and eating patterns. It could elevate the implicit craving which was measured after the questionnaires by causing a priming effect. In this study, the investigation of attentional bias was conducted after the questionnaire because the external eaters' state could be changed when they are exposed to the food-related cues like the picture of food. Taking into account the priming effect of food-related thoughts caused by completing questionnaires, measuring craving before conducting questionnaires might be required in a future study.

Despite these limitations, this study has some implications. This study is the first to examine the effects of cognitive load on VSWM in EEs. As external eating is a problematic eating style in this obesogenic environment, intervening with external eating tendencies is necessary considering the risk for obesity. Cognitive load might have a benefit as an active intervention for EE in reducing food intake when they are exposed to food-related stimuli. Second, although most previous studies find out the effects of cognitive load by self-reported questionnaires, this study examined the effects of cognitive load by physiological measure (i.e., eye-tracking device) which is relatively free from intentional responses. As eye-tracking data had been turned out to be a reliable index in substance or food craving research (Sayette, 2016), this study may develop results from previous studies with an implicit measure of cravings. In conclusion, the current study demonstrated that EEs' craving is significantly affected by the cognitive load on VSWM. Their implicit craving, however, decreased when they conducted an arithmetic task. This result highlights the importance of interrupting elaboration of intrusive thoughts toward food cues and therefore preventing craving for foods.

References

Andrade, J., May, J., & Kavanagh, D. (2012). Sensory imagery in craving: From cognitive psychology to new treatments for addiction. *Journal of Experimental Psychopathology, 3*, 127-145.

Andres, M., Michaux, N., & Pesenti, M. (2012). Common substrate for mental arithmetic and finger representation in the parietal cortex. *Neuroimage, 62*, 1520-1528.

Baumeister, R. F., Bratslavsky, E., Muraven, M., & Tice, D. M. (1998). Ego depletion: Is the active self a limited resource? *Journal of Personality and Social Psychology, 74*, 1252-1265.

Blechert, J., Meule, A., Busch, N. A., & Ohla, K. (2014). Food-pics: An image database for experimental research on eating and appetite. *Frontiers in Psychology, 5*, 617.

Burton, P., Smit, H. J., & Lightowler, H. J. (2007). The influence of restrained and external eating patterns on overeating. *Appetite, 49*, 191-197.

Chaput, J. P., Gilbert, J. A., Gregersen, N. T., Pedersen, S. D., & Sjödin, A. M. (2010). Comparison of 150-mm versus 100-mm visual analogue scales in free living adult subjects. *Appetite, 54*, 583-586.

Chong, R. K., Mills, B., Dailey, L., Lane, E., Smith, S., & Lee, K. H. (2010). Specific interference between a cognitive task and sensory organization for stance balance control in healthy young adults: Visuospatial effects. *Neuropsychologia, 48*, 2709-2718.

Fennema, E., & Sherman, J. A. (1976). Fennema-Sherman mathematics attitudes scales: Instruments designed to measure attitudes toward the learning of mathematics by females and males. *Journal for Research in Mathematics Education, 7*, 324-326.

Field, M., Mogg, K., Zetteler, J., & Bradley, B. P. (2004). Attentional biases for alcohol cues in heavy and light social drinkers: The roles of initial orienting and maintained attention. *Psychopharmacology, 176*, 88-93.

Forestell, C. A., Lau, P., Gyurovski, I. I., Dickter, C. L., & Haque, S. S. (2012). Attentional biases to foods: The effects of caloric content and cognitive restraint. *Appetite, 59*, 748-754.

Gable, P. A., & Harmon-Jones, E. (2010). Late positive potential to appetitive stimuli and local attentional bias. *Emotion, 10*, 441-446.

Gormally, J., Black, S., Daston, S., & Rardin, D. (1982). The assessment of binge eating severity among obese persons. *Addictive Behaviors, 7*, 47-55.

Grand, S. (1968). Color-word interference: An investigation of the role of vocal conflict and hunger in associative priming. *Journal of Experimental Psychology, 77*, 31-40.

Heeren, A., Philippot, P., & Koster, E. H. (2015). Impact of the temporal stability of preexistent attentional bias for threat on its alteration through attention bias modification. *Journal of Behavior Therapy and Experimental Psychiatry, 49*, 69-75.

Hou, R., Mogg, K., Bradley, B. P., Moss-Morris, R., Peveler, R., & Roefs, A. (2011). External eating, impulsivity and attentional bias to food cues. *Appetite, 56*, 424-427.

Imbo, I., & LeFevre, J. A. (2010). The role of phonological and visual working memory in complex arithmetic for Chinese-and Canadian-educated adults. *Memory & Cognition, 38*, 176-185.

Kakoschke, N., Kemps, E., & Tiggemann, M. (2015). Combined effects of cognitive bias for food cues and poor inhibitory control on unhealthy food intake. *Appetite, 87*, 358-364.

Kemps, E., Tiggemann, M., Martin, R., & Elliott, M. (2013). Implicit approach–avoidance associations for craved food cues. *Journal of Experimental Psychology: Applied, 19*, 30-38.

Kim, H., Lee, Y., & Kim, J. (1996). A Study of the reliability and validity of the Korean version of the Eating Behavior Questionnaire. *Korean Journal of Clinical Psychology, 15*, 141-150.

Larsen, H., Engels, R. C., Wiers, R. W., Granic, I., & Spijkerman, R. (2012). Implicit and explicit alcohol cognitions and observed alcohol consumption: Three studies in (semi) naturalistic drinking settings. *Addiction, 107*, 1420-1428.

Lee, K. M., & Kang, S. Y. (2002). Arithmetic operation and working memory: Differential suppression in dual tasks. *Cognition, 83*, B63-B68.

Lee, S. (2012). Development of the Mathematics Self-Efficacy Scale for high school and college students. *The Korean Journal of Counselling and Psychotherapy, 24*, 573-594.

MacLeod, C., Rutherford, E., Campbell, L., Ebsworthy, G., & Holker, L. (2002). Selective attention and emotional vulnerability: Assessing the causal basis of their association through the experimental manipulation of attentional bias. *Journal of Abnormal Psychology, 111*, 107-123.

Masson, N., & Pesenti, M. (2014). Attentional bias induced by solving simple and complex addition and subtraction problems. *The Quarterly Journal of Experimental Psychology, 67*, 1514-1526.

May, J., Andrade, J., Panabokke, N., & Kavanagh, D. (2004). Images of desire: Cognitive models of craving. *Memory, 12*, 447-461.

May, J., Kavanagh, D. J., & Andrade, J. (2015). The elaborated intrusion theory of desire: A 10-year retrospective and implications for addiction treatments. *Addictive Behaviors, 44*, 29-34.

Mitchison, D., & Hay, P. J. (2014). The epidemiology of eating disorders: Genetic, environmental, and societal factors. *Clinical Epidemiology, 6*, 89-97.

Müller, N., Baumeister, S., Dziobek, I., Banaschewski, T., & Poustka, L. (2016). Validation of the movie for the assessment of social cognition in adolescents with ASD: Fixation duration and pupil dilation as Predictors of Performance. *Journal of Autism and De-*

https://doi.org/10.15842/kjcp.2020.39.2.004

velopmental Disorders, 46, 2831-2844.

Nijs, I. M., Muris, P., Euser, A. S., & Franken, I. H. (2010). Differences in attention to food and food intake between overweight/obese and normal-weight females under conditions of hunger and satiety. *Appetite, 54*, 243-254.

Nijs, I. M. T., Franken, I. H. A., & Muris, P. (2009). Enhanced processing of food-related pictures in female external eaters. *Appetite, 53*, 376-383.

Park, S., & Park, A. (2008). The Effects of the K-Nectar Program Using Reality Therapy on the Body Image and Binge Eating Habits of Female College Students. *The Korean Journal of Counselling and Psychotherapy, 20*, 43-64.

Pessoa, L., & Adolphs, R. (2010). Emotion processing and the amygdala: From a 'low road' to 'many roads' of evaluating biological significance. *Nature Reviews Neuroscience, 11*, 773-783.

Sayette, M. A. (2016). The role of craving in substance use disorders: Theoretical and methodological issues. *Annual Review of Clinical Psychology, 12*, 407-433.

Sharbanee, J. M., Stritzke, W. G., Jamalludin, M. E., & Wiers, R. W. (2014). Approach-alcohol action tendencies can be inhibited by cognitive load. *Psychopharmacology, 231*, 967-975.

Skorka-Brown, J., Andrade, J., & May, J. (2014). Playing 'Tetris' reduces the strength, frequency and vividness of naturally occurring cravings. *Appetite, 76*, 161-165.

Tiggemann, M., Kemps, E., & Parnell, J. (2010). The selective impact of chocolate craving on visuospatial working memory. *Appetite, 55*, 44-48.

Van Dillen, L. F., & Andrade, J. (2016). Derailing the streetcar named desire. Cognitive distractions reduce individual differences in cravings and unhealthy snacking in response to palatable food. *Appetite, 96*, 102-110.

Van Dillen, L. F., Papies, E. K., & Hofmann, W. (2013). Turning a blind eye to temptation: How cognitive load can facilitate self-regulation. *Journal of Personality and Social Psychology, 104*, 427-443.

Van Strien, T., Frijters, J. E., Bergers, G., & Defares, P. B. (1986). The Dutch Eating Behavior Questionnaire (DEBQ) for assessment of restrained, emotional, and external eating behavior. *International Journal of Eating Disorders, 5*, 295-315.

Van Strien, T., Herman, C. P., Anschutz, D. J., Engels, R. C., & de Weerth, C. (2012). Moderation of distress-induced eating by emotional eating scores. *Appetite, 58*, 277-284.

Vohs, K. D., & Heatherton, T. F. (2000). Self-regulatory failure: A resource-depletion approach. *Psychological Science, 11*, 249-254.

Ward, A., & Mann, T. (2000). Don't mind if I do: Disinhibited eating under cognitive load. *Journal of Personality and Social Psychology, 78*, 753-763.

Werthmann, J., Roefs, A., Nederkoorn, C., Mogg, K., Bradley, B. P., & Jansen, A. (2011). Can (not) take my eyes off it: Attention bias for food in overweight participants. *Health Psychology, 30*, 561-569.

Wiers, R. W., & Stacy, A. W. (2006). Implicit cognition and addiction. *Current Directions in Psychological Science, 15*, 292-296.

Witcomb, G. L. (2005). *Effects of cognitive distraction on the regulation of human eating behaviour* (Doctoral dissertation). Loughborough University, London, UK.