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Hand-Held Dynamic Visual Noise Reduces Naturally Occurring Food Cravings and Craving-Related Consumption

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Abstract

This study demonstrated the applicability of the well-established laboratory task, dynamic visual noise, as a technique for reducing naturally occurring food cravings and subsequent food intake. Dynamic visual noise was delivered on a hand-held computer device. Its effects were assessed within the context of a diary study. Over a 4-week period, 48 undergraduate women recorded their food cravings and consumption. Following a 2-week baseline, half the participants watched the dynamic visual noise display whenever they experienced a food craving. Compared to a control group, these participants reported less intense cravings. They were also less likely to eat following a craving and consequently consumed fewer total calories following craving. These findings hold promise for curbing unwanted food cravings and craving-driven consumption in real-world settings.

Keywords: food craving; craving reduction; dynamic visual noise; personal digital assistant (PDA); consumption

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The term 'craving' is defined as a motivational state in which an individual feels compelled to seek and ingest a particular substance (Baker, Morse & Sherman, 1986). Although it usually refers to tobacco, alcohol and drugs, the construct applies equally to food. Thus, food cravings have been described as an intense desire or urge to eat a specific food (Weingarten & Elston, 1990). It is this specificity that distinguishes a food craving from feelings of ordinary hunger (Pelchat, 2002). Food cravings originate from a range of both physiological and psychological sources, including nutritional deficiencies (Wardle, 1987), hormonal changes (Dye, Warner & Bancroft, 1995), negative emotional states (Hill, Weaver & Blundell, 1991) and exposure to the sight or smell of tasty food (Fedoroff, Polivy & Herman, 2003). Experimentally, high caloric food cueing has been shown to increase self-reported craving and activation in the brain's reward system (i.e., corticolimbic circuitry) (Asmaro et al., 2012; Kemps & Tiggemann, 2007; Pelchat, Johnson, Chan, Valdez & Ragland, 2004; Rolls & McCabe, 2007). In addition, food cue driven activity in the nucleus accumbens, a key brain structure involved in regulating motivation and reward (Cauda et al., 2011; Krebs, Boehler, Egner & Woldorff, 2011), has been linked to subsequent snack food consumption (Lawrence, Hinton, Parkinson & Lawrence, 2012).

Unlike cravings for alcohol, tobacco and drugs, cravings for food are generally not pathological. In fact, occasional food cravings occur among a large proportion of the general population without any problem (Lafay et al., 2001). Nevertheless, recurrent food cravings can be maladaptive for some people, and may even pose health risks. In particular, food cravings have the potential to disrupt and thwart dieting attempts (Sitton, 1991), leading to feelings of guilt and shame (Macdiarmid & Hetherington, 1995). They have also been shown to impair cognitive performance (Kemps, Tiggemann & Grigg, 2008), and have been linked to overeating in obese individuals (Schlundt, Virts, Sbrocco & Pope-Cordle, 1993) and binge eating in women with bulimia nervosa (Waters, Hill & Waller, 2001). Thus there is a genuine need for effective and accessible techniques for curbing problematic food cravings.

Over recent years, a growing number of laboratory studies have shown that performing visual or olfactory tasks can reduce food cravings. For example, Kemps and colleagues (Harvey, Kemps & Tiggemann, 2005; Kemps & Tiggemann, 2007) showed that asking participants to read scripts that asked them to imagine common sights (e.g., a rainbow) or smells (e.g., eucalyptus) reduced cravings for food and chocolate in a way that imagining everyday sounds (e.g., a siren) did not. Similar reduction effects have been reported for cigarette (May, Andrade, Panabokke & Kavanagh, 2010; Versland & Rosenberg, 2007) and caffeine cravings (Kemps & Tiggemann, 2009).

Non-imagery tasks in the visual and olfactory domain, such as making hand or eye movements (Kemps, Tiggemann, Woods & Soekov, 2004; McClelland, Kemps & Tiggemann, 2006), constructing shapes from modelling clay (Andrade, Pears, May & Kavanagh, 2012), or smelling an unfamiliar or non-food odour (Kemps & Tiggemann, 2013; Kemps, Tiggemann & Bettany, 2012) have also been shown to reduce food cravings. However, the most widely experimentally-supported craving reducing technique is dynamic visual noise (Kemps et al., 2004; Kemps, Tiggemann & Christianson, 2008; Kemps, Tiggemann & Hart, 2005; May et al., 2010; McClelland et al., 2006; Steel, Kemps & Tiggemann, 2006). This visual task involves exposure to a flickering pattern of black and white dots (Quinn & McConnell, 1996a), which participants watch while they experience a craving. This has been shown to reduce food cravings in the laboratory, relative to its auditory equivalent, irrelevant speech, or a no-task control condition (Kemps et al., 2004, 2005, 2008; McClelland et al., 2006; Steel et al., 2006). More generally, dynamic visual noise is a well-established task within the working memory literature (where it originated) and has been shown to interfere with visual imagery (Andrade, Kemps, Werniers, May & Szmalec, 2002; Baddeley and Andrade, 2000; Dean, Dewhurst, Morris & Whittaker, 2005; McConnell & Quinn, 2000; Quinn and McConnell, 1996a,b, 1999), indicating mutual competition for limited-capacity visual working memory.

These findings are consistent with cognitive-motivational accounts of craving, in particular the Elaborated Intrusion (EI) Theory of Desire (Kavanagh, Andrade & May, 2005, 2009). This theory proposes that cravings are enabled by both bottom-up and top-down processes. More specifically, within this framework, a craving episode consists of two stages: an initial intrusive thought about a desired target followed by a process of cognitive elaboration. The appetitive thought is triggered by bottom-up precursors such as internal need states (e.g., substance deprivation), negative mood and environmental cues (e.g., high caloric food cues), and activates the brain reward system (Hofmann & Van Dillen, 2012). The thought, because it is pleasurable, is then enriched in a top-down fashion, involving in particular the construction, maintenance and manipulation of sensory images of the desired target. Berridge and Robinson (2003) have suggested that vivid mental images of reward might activate dopaminergic reward pathways via top-down projections to the prefrontal cortex.

EI theory places mental imagery at the heart of the food craving experience. In support, anecdotal reports and survey studies show that people have vivid mental images of the craved food during a craving episode (Green, Rogers & Elliman, 2000). Moreover, these food images pertain predominantly to the visual and olfactory sensory modalities (May, Andrade, Panabokke & Kavanagh, 2004; Tiggemann & Kemps, 2005). Neuroimaging research further supports a role for mental imagery in craving. For example, Wang et al. (2007) showed an association between cigarette craving and activation of cortical areas (including the prefrontal cortex) implicated in mental imagery and memory.

According to EI theory, top-down control processes can prevent or disrupt the cognitive elaboration of intrusive thoughts. Specifically, competing cognitive demands from modality-specific (e.g., visual and olfactory) tasks selectively block craving-related imagery by introducing information into the same sensory modality, thereby competing for limited cognitive resources. Thus, dynamic visual noise has its craving reducing effect by reducing the vividness of visual craving-related imagery (Kemps et al., 2004, 2005, 2008; McClelland et al., 2006; Steel et al., 2006). Neuroimaging studies on appetitive regulation (for a review, see Heatherton & Wagner, 2011) suggest that the craving reducing effect of dynamic visual noise reflects top-down control from the prefrontal cortex over the subcortical regions involved in reward.

The craving reduction studies described earlier have all been conducted in the laboratory. The aim of the present study was to extend this research to the field and to test the applicability of dynamic visual noise as a technique for curbing naturally occurring food cravings. Watching the dynamic visual noise display is a relatively simple and straightforward task, making it a readily acceptable and practical craving reduction tool. It also has the advantage of being easily incorporated into existing technologies such as smart phones and other mobile hand-held devices.

In addition to investigating the effect of dynamic visual noise on everyday food cravings, we also examined its effect on consumption following craving. Because unwanted consumption is at the heart of craving-related eating problems (Schlundt et al., 1993; Waters et al., 2001), it is important to determine whether dynamic visual noise can also reduce food intake in response to cravings. This has not previously been tested (neither in the laboratory nor in the field). According to EI theory, craving-related imagery provides a mental link between appetitive thoughts and actual consumption (Andrade, May & Kavanagh, 2012). Thus, it was predicted that dynamic visual noise would disrupt this link, and hence, reduce craving-driven food intake.

Method

Participants

Participants were 48 female undergraduate students at Flinders University. We specifically recruited a sample of women, because food cravings are more prevalent in women than in men (Weingarten & Elston, 1991). Participants were aged between 18 and 29 years (*M* = 21.27, *SD* = 2.35) and were mostly of normal weight. Mean BMI for the sample was 22.48 (*SD* = 3.70). Participants had their last menstrual period starting 17.21 days ago (*SD* = 12.28). Twenty-five participants used oral contraception[1]. Only participants who had a food craving at least 7 times per week were recruited into the study. On average, participants experienced 11.46 (*SD* = 4.63) food cravings per week. Participants were paid an honorarium of $200 in lieu of their time and commitment.

Design

The research design took the form of a self-report diary study. During a 4-week period, participants recorded their food cravings and consumption. The first two weeks served as a baseline, followed by the intervention in the subsequent two weeks. Accordingly, two weeks into the study, half the participants were issued with hand-held computer devices which displayed the dynamic visual noise. They were instructed to look at the display whenever they experienced a food craving. The other half functioned as a control group. Participants in this group simply continued to record their food cravings and eating as before. Participants were randomly assigned to the two groups, subject to equal numbers (N = 24) per group.

Materials and Procedure

All participants completed two diaries about their food cravings and eating. Each diary covered a period of two weeks. All participants attended a group information session, prior to completing each diary. In the first information session, participants received the first diary and were given instructions on how to complete it. Adhering to instructions as well as accuracy and honesty in record keeping were stressed. Participants were told to have the diary with them at all times and to complete it every time they ate anything and every time they had a food craving. For every eating episode, participants indicated whether they had a meal or a snack. For every food craving, participants recorded the time at which they experienced the craving, the food they had craved and what had triggered the craving. They also indicated the intensity of the craving by placing a vertical mark on a 100-mm visual analogue scale, ranging from “not at all intense” to “very intense”. Additionally, participants circled ‘yes’ or ‘no’ as to whether they had eaten in response to the craving, and if so, were asked to describe what they had eaten and how much. Participants were instructed to report the specific food and quantity eaten (e.g., 2 scoops of vanilla ice-cream, 3 fun-size chocolate bars, 6 chicken nuggets, 20g salted cashews, 150g hot chips) to enable the researchers to subsequently estimate the number of calories consumed. Finally, participants circled ‘yes’ or ‘no’ as to whether they had tried to resist the craving. Responses to these items provided baseline data on food craving and consumption.

In the second information session, participants returned their first completed diary and received the second diary, plus instructions on how to complete it. Participants in the control and dynamic visual noise conditions attended separate information sessions. Participants in the control condition were instructed to complete the second diary in exactly the same way as they had completed the first one.

Participants in the dynamic visual noise condition were given a Personal Data Assistant (PDA) in addition to the second diary. They were asked to record their eating episodes as they had done in Diary 1. However, whenever they experienced a food craving, they were to turn on the PDA and tap the screen. The PDA would display the dynamic visual noise array. This consisted of an 80 × 80 grid of 4 × 4 black and white pixel squares. Random squares changed from black to white or white to black at a rate of 640 changes per second, creating a flickering effect. The dynamic visual noise remained on screen for 8 sec. Participants could watch it as often as they liked by tapping again on the screen. To minimise potential demand effects, participants were explicitly told that using the PDA might or might not affect the craving, and so, the craving might “become more or less intense, or stay the same”.

Participants were shown how to use the PDA and how to charge it, and were given practice at using it. Participants were instructed to complete a modified craving record for each food craving. In addition to recording the time at which they experienced the craving, the food they had craved and what had triggered the craving, as they had done in Diary 1, they also rated the intensity of their food craving, both when it had started and after using the PDA. As in Diary 1, they rated these craving intensities on 100-mm visual analogue scales, ranging from “not at all intense” to “very intense”. Participants furthermore circled ‘yes’ or ‘no’ as to whether they had used the PDA, and if so, recorded the number of times they had watched the dynamic visual noise display. Finally, participants circled ‘yes’ or ‘no’ as to whether they had eaten in response to the craving, and if so, described precisely what they had eaten and how much. These data enabled us to assess the effect of the intervention.

Results

Characteristics of Food Craving and Eating Episodes

For the two-week baseline, participants ate on average two to three meals (M = 2.55, SD = .36) and two snacks (M = 2.05, SD = .62) per day. They further reported having over one food craving episode per day (M = 1.34, SD = .55). Most cravings occurred in the afternoon (40%) and early evening (22%). Chocolate was by far the most frequently craved food (29%), followed by other sweets and confectionery (15%) and savoury (10%) food. Cravings were most often triggered by exposure to food cues (e.g., in shops, on television, other people eating) (33%), hunger (22%), thinking about food (13%) and negative emotions such as boredom and stress (9%). Mean ratings of food craving intensity were a little above the mid-point of the scale (M = 55.16, SD = 13.85). Forty-two per cent of cravings led to food intake, with participants consuming on average 2581 calories (SD = 1658) in response to craving over the 2-week period. Participants reported that they tried to resist their cravings on about a third (35%) of occasions. As can be seen in Table 1, there were no initial differences in these food craving and eating characteristics between the two experimental groups.

Effect of Dynamic Visual Noise on Food Craving Intensity

During the two-week intervention, participants in the dynamic visual noise group reported using the PDA for 72% of their food craving episodes, and watched the dynamic visual noise display on average 3.15 times (*SD* = 1.93) per episode. They rated the intensity of their food cravings twice, before and again after using the PDA. As predicted, a paired samples *t* test showed that craving intensity ratings were significantly lower after participants had used the PDA (*M* = 45.54, *SD* = 11.19) than before (*M* = 59.10, *SD* = 13.69), $t(23) = 6.27$, $p < .001$, $d = 1.09$. Specifically, dynamic visual noise reduced craving intensity by 23%. An independent samples *t* test further showed that initial craving intensity ratings (i.e., before using the PDA) did not differ from those in the control group (*M* = 61.10, *SD* = 18.33), $t(46) = .43$, $p = .67$.

Effect of Dynamic Visual Noise on Craving-Related Consumption

A 2 (group: control, dynamic visual noise) × 2 (time: baseline, intervention) mixed model ANOVA was conducted to determine the effect of dynamic visual noise on craving-related consumption. The latter was calculated as the proportion of craving episodes that were followed by food intake. There were no main effects of group, $F(1, 46) = .27$, $p = .61$, or time, $F(1, 46) = 3.49$, $p = .07$. However, as can be seen in Figure 1, there was the predicted significant group × time interaction, $F(1, 46) = 4.47$, $p = .04$, partial $\eta^2 = .08$. Planned comparisons showed that participants in the dynamic visual noise condition were significantly less likely to eat following a craving in Diary 2 (with PDA) than in Diary 1, $t(23) = 3.15$, $p = .005$, $d = .50$. Specifically, dynamic visual noise reduced the likelihood of craving-driven consumption by 39%. In contrast, the control group showed no differences in food intake between the two diaries, $t(23) = .16$, $p = .88$.

Furthermore, this reduction in number of episodes of craving-related consumption in the dynamic visual noise group resulted in a reduction in food intake. Total amount of food eaten in response to craving was converted into calories. A 2 (group: control, dynamic visual noise) × 2 (time: baseline, intervention) mixed model ANOVA performed on this variable showed no main effects of group, $F(1, 46) = .85$, $p = .36$, or time, $F(1, 46) = 1.22$, $p = .28$. However, as shown in Figure 2, the group × time interaction, $F(1, 46) = 6.90$, $p = .01$, partial $\eta^2 = .13$, was statistically significant. Participants in the dynamic visual noise condition consumed fewer total calories following craving in Diary 2 than in Diary 1, $t(23) = 3.25$, $p = .004$, $d = .49$. Specifically, dynamic visual noise reduced craving-driven calorie intake by 31%. By contrast, calorie intake in response to craving did not differ between the two diaries in the control group, $t(23) = .93$, $p = .36$.

Discussion

Baseline data confirm findings from earlier food craving research. Participants displayed normative eating behaviour consistent with eating patterns in contemporary Westernised countries (Freedman, 2007), consuming on average two to three meals, and two snacks per day. In line with previous food craving studies (Hill & Heaton-Brown, 1994; Weingarten & Elston, 1991), participants reported on average a little more than one food craving per day. As is often found in university student samples (May et al., 2004; Tiggemann & Kemps, 2005), ratings of craving intensity were a little above the mid-point of the scale. Consistent with other food craving diary studies (Hill et al., 1991), cravings occurred mostly after midday, throughout the afternoon and early evening. Not surprisingly, chocolate and chocolate-containing foods were by far the most frequently craved items, followed by other sweets and confectionery, and savoury foods. This fits with chocolate's unique status as the most commonly and intensely craved food in Western culture (Hetherington & Macdiarmid, 1993). Cravings were most often triggered by cue exposure, hunger, thoughts about food and negative affect, commonly reported triggers of craving (Hill et al., 1991; Hill & Heaton-Brown, 1994; Tiggemann & Kemps, 2005). As has been shown previously (Hill et al., 1991; Weingarten & Elston, 1991), participants did try to resist their craving about one third of the time.

The main focus of the current study was to determine the effects of dynamic visual noise on naturally occurring food cravings and subsequent food intake. As predicted, dynamic visual noise reduced the intensity of participants' food cravings. This confirms previous laboratory-based reports of dynamic visual noise effects on craving reduction (Kemps et al., 2004, 2005, 2008; May et al., 2010; McClelland et al., 2006; Steel et al., 2006). It thereby extends the use of dynamic visual noise as a technique for reducing experimentally induced food cravings in the laboratory to everyday cravings in real-world settings.

Importantly, dynamic visual noise also reduced craving-driven consumption. Specifically, dynamic visual noise significantly reduced the likelihood of food intake in response to craving, and consequently the amount of calories consumed. These findings extend the application of dynamic visual noise from a craving reduction technique to one that also modifies actual food intake. This has considerable scope for tackling unwanted (over)consumption that results from food cravings, as experienced by a number of different people, including individuals actively trying to lose weight (Sitton, 1991), binge eaters (Waters et al., 2001), and some obese individuals (Schlundt et al., 1993).

The effects of dynamic visual noise on craving and consumption are consistent with the predictions of EI theory. Specifically, dynamic visual noise has its craving reducing effect by interfering with visual craving-related imagery, through mutual competition for limited-capacity visual working memory. Additionally, as craving-related imagery provides a mental link between the initial appetitive intrusive thought, interference from dynamic visual noise would have served to weaken this link, thereby reducing food intake. The current findings also fit with more biologically oriented top-down models of appetitive behaviour regulation (Heatherton & Wagner, 2011). In this latter framework, dynamic visual noise may serve to block the processing of high caloric food cues in the brain reward system (i.e., prevent or interrupt craving-related imagery) via top-down control from the prefrontal cortex, leading to reductions in craving and consumption.

The dynamic visual noise effects on food craving and intake reduction observed here in a real-world context show that the technique clearly has potential as a self-help tool. The software could easily be developed as ‘an app’ to be downloaded on the now popular smart phones or other hand-held computer devices that many people carry with them. Thus the technique could be readily accessible in a discreet manner virtually anywhere and anytime a food craving arises.

A number of limitations of the present study need to be acknowledged. First, the dynamic visual noise intervention was compared against a no-task control condition. Thus the observed reductions in food craving intensity and craving-related consumption could simply reflect general cognitive distraction. However, this is unlikely, as dynamic visual noise has been shown to more effectively reduce food cravings than its verbal counterpart, irrelevant speech, in the laboratory (Kemps et al., 2005). Nevertheless, future field studies could usefully include a non-visual control task, also administered via PDA, to provide a stronger test of the dynamic visual noise intervention. Second, although we have a measure of calorie intake following craving, we have no indication of total calorie intake, because we asked participants to record only when they had a meal or snack, without specifying what they ate. Future studies could examine the effect of dynamic visual noise on overall calorie intake in addition to craving-related intake. Third, we had only a relatively crude measure of menstrual cycle. Several studies have found increased food craving (Dye et al., 1995) and consumption (Barr, Janelle & Prior, 1995; Johnson, Corrigan, Lemmon, Bergeron & Crusco, 1994), as well as high caloric food cue reactivity in the brain reward system (Frank, Kim, Krzemien & Van Vugt, 2010) during the luteal phase of the menstrual cycle. Future research could explicitly examine the effect of menstrual phase on craving and craving-reduction. Finally, the current sample consisted of female university students who reported food cravings of only moderate intensity. Future research should aim to extend the present findings to individuals who experience frequent and/or intense food cravings, such as “chocoholics”, as well as binge eaters, overweight or obese individuals who are trying to lose weight, and those suffering from bulimia nervosa (Schlundt et al., 1993; Sitton, 1991; Waters et al., 2001). Studies should also include men, who similarly to women suffer from obesity and craving-induced overeating. Future research could also endeavour to extend the current protocol to cravings for other substances, such as alcohol, tobacco and drugs, which, like those for food, have a visual imagery basis (May et al., 2004).

In conclusion, the present study demonstrated the applicability of the well-established laboratory task, dynamic visual noise, as a technique for reducing naturally occurring food cravings. It also showed for the first time that this technique can be used to modify craving-driven food intake.

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Footnotes

1. Controlling for the variables 'days since start of last menstrual period' and 'use of oral contraception' in the analyses on food craving intensity and craving-related consumption did not alter the pattern of results.

Table 1

Characteristics of Food Craving and Eating Episodes for Each Group at Baseline (i.e., Diary 1)

	Control	Dynamic visual noise
Eating		
No. of meals per day	2.43 (.36)	2.67 (.33)
No. of snacks per day	1.94 (.50)	2.16 (.72)
Food craving		
No. of cravings per day	1.41 (.62)	1.26 (.48)
Time of day		
Afternoon	41%	40%
Early evening	19%	25%
Food craved		
Chocolate	29%	29%
Other sweets and confectionery	15%	14%
Savoury food	11%	10%
Triggers		
Food cues	34%	32%
Hunger	19%	26%
Thinking about food	10%	16%
Negative emotions	9%	9%
Craving intensity	55.63 (15.58)	54.68 (12.19)
Cravings followed by food intake	.40 (.40)	.44 (.40)
Calorie intake following craving	2507 (1313)	2654 (1970)
% of cravings resisted	37%	33%

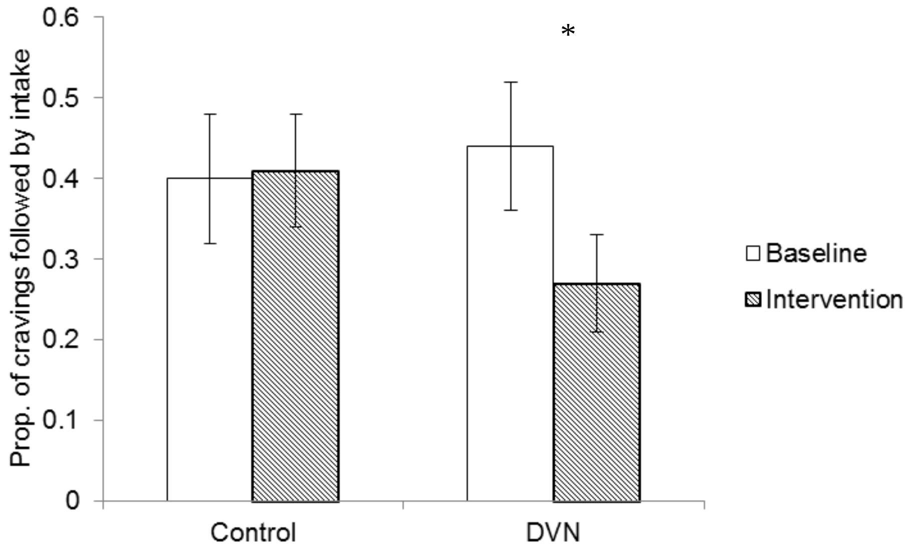

Figure 1. Proportion of craving episodes followed by food intake for each of the experimental groups at baseline and intervention; * $p < .01$. DVN = dynamic visual noise.

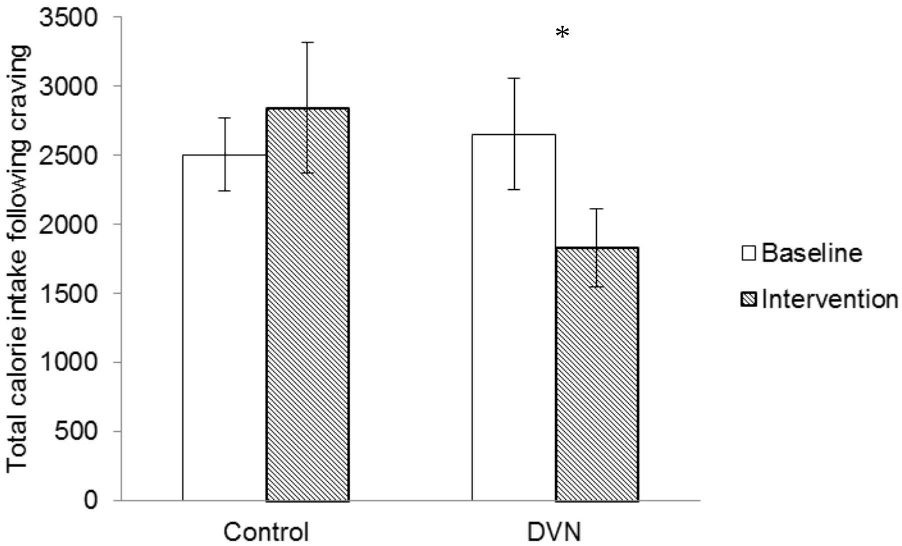

Figure 2. Total calorie intake in response to craving for each of the experimental groups at baseline and intervention; * $p < .01$. DVN = dynamic visual noise.