Individual differences and food-cue reactivity: Predictors of BMI, portion size, and everyday dietary behaviour.

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RESEARCH REPORT

- **Background**

Despite the fact that the health and economic consequences associated with obesity and overweight are well documented (House of Commons Report, 2001), an increasing proportion of the UK population now fall into one of these categories (Swan, 2004). In children, this problem is a particular concern. Recently, it has been estimated that 22% of boys and 28% of girls are either overweight or obese (approximately 1 million) (Chinn & Rona, 2001). In response, The Government has now set a target to halt this increase by 2010 (Sure Start, 2004).

In the late 1960s Schachter and his colleagues developed a highly influential proposal that became known as the ‘externality theory of human obesity’ (Schachter, 1968; Schachter & Rodin, 1974). This theory argues that the obesity (and overeating) occurs because certain individuals are less sensitive to internal hunger and satiation cues, and are relatively more sensitive to external cues, including the sensory characteristics of food. Despite this early work, basic questions about the process that leads to overeating remain unexplored. In particular, it has recently become clear that food-cue exposure (exposure to the sight or smell of food) is extremely important. In animal-based research, ‘food-cue reactivity’ has been described as a ‘conditioned appetitive response.’ The sight and smell of food (the food cue) can have a powerful effect on appetite. Indeed, food cues are found to initiate feeding behaviour even in the absence of immediate nutritional deprivation (Weingarten, 1983).

In humans, food-cue exposure has a similar effect, influencing both our momentary desire for food (Fedforoff, Polivy, & Herman, 1997; Rogers & Hill, 1989) and our preparedness to consume it (Brunstrom, Yates, & Witcomb, 2004). Despite this, important questions remain unresolved. For example, some individuals appear to be more reactive to food cues than others. And, this difference is probably indicative of important underlying variation in our relationship with food. Consistent with this idea, levels of food-cue reactivity are found to correlate with behaviours such as dieting (Stirling & Yeomans, 2004) and binge eating (Sobik, 2005; Carter, Bulik, & McIntosh, 2002). In relation to weight gain, this later finding is highly relevant, because up to 46% of obese people report binge eating (for a review see Bulik, Sullivan, & Kendler, 2002). In addition, Jensen et al. (2003) have reported that food cues have the capacity to stimulate overeating, and this is especially the case in children who are overweight. This is highly relevant, because it suggests that bodyweight and cue reactivity might be related causally.
If cue reactivity is an important predictor of over-consumption and weight gain, then intervention techniques might be developed that target this association (e.g., Jansen 1998). However, food-cue exposure probably influences a wide range of physiological and psychological (dispositional) variables. Before targeted treatments can be considered, two specific questions need to be addressed. These are outlined in the ‘objectives’ section below. This section also includes an account of how each objective was met.

- **Objectives**

**Objective 1: By what process does food-cue exposure induce over-consumption of food?**

*Background*

Exposure to a pleasant food cue is likely to change a person’s momentary predilection to consume food. However, the process that links cue exposure to over-consumption is unclear. For example, although exposure might increase an expression of desire for food, it remains unclear whether this involves a concomitant increase in the ideal amount of food that is desired or an increase in the portion size that is tolerated at that moment in time. This issue was resolved by taking a range of measures in a controlled environment.

*Research addressing objective 1*

Pilot work: In the first instance it was necessary to develop new methods for measuring i) prospective intake of foods (an amount that a person would like to consume at the time of asking) and ii) the extent to which a person would tolerate consuming a portion that is larger than this ideal. New computer programs were written and photographic images were taken of foods in different portion sizes. Together, these were used to develop novel psychophysical paradigms (for a description see the ‘Methods’ section below). In the original proposal two experiments were described. However, this additional pilot work was justified on the grounds that these techniques required validation and refinement. The results from this work indicated that very accurate measures of portion size can be obtained and that these techniques have several advantages over the methods described in the original proposal. Forty participants were tested as part of this pilot work.

*Study 1: This study explored the process by which cue exposure leads to over-consumption of food. Three hypotheses were tested:*

1. Exposure to a food cue increases the amount people want and plan to eat
2. Exposure to a food cue increases tolerance of larger portion sizes
3. Exposure to a food cue delays the development of satiety

In addition to these hypotheses (as outlined in the original proposal), the PI also explored the extent to which the effects of cue exposure are specific or general. In both animals (Weingarten, 1985) and humans (Cornell, Rodin, & Weingarten, 1989; Fedoroff, Polivy, & Herman, 2003) cue exposure is thought to promote the
consumption of the cued food but to have little effect on motivation to consume non-cued foods (Fedoroff, Polivy, & Herman, 2003). However, a potential problem with these studies is that very different kinds of foods have been used (e.g., cookies and pizza). Hence, it remains unclear whether evidence for specificity necessarily requires very dissimilar foods to be compared. Here, this issue was explored by comparing the effects of cue exposure (desire to eat and prospective portion size) in both the cued food and a range of similar and dissimilar non-cued foods. Hot pizza was used as the cued food and ‘cake,’ ‘pasta and tomato sauce,’ and ‘scrambled eggs, chips, and baked beans’ were non-cued foods.

Fifty female students participated in this experiment. Each was tested on two separate days. On one day, they were exposed to the sight and smell of a freshly baked pizza (the “cue” condition). On the other day, they took part in a simple cognitive task (the “no cue” condition). The ordering of the cue and the no-cue condition was counterbalanced across participants. In both conditions, participants provided a measure of their ideal prospective pizza-portion size and the maximum pizza-portion that they would tolerate both before and after the cue/cognitive task. At the same time, measures were taken of prospective portion size and desire to eat, both for pizza and for three non-cued foods/meals; cake, ‘pasta and tomato sauce,’ and ‘scrambled eggs, chips, and baked beans.’ In both conditions, the participants were then given a fixed portion of pizza to consume. Once they had eaten this portion, they were asked to complete ratings of hunger and fullness. Afterwards, they were instructed to consume pizza until they no longer wished to do so. A schematic of the test procedure is provided in Figure 1.

**Figure 1. Schematic of procedure in Study 1.**
Findings from study 1

Several important findings emerged from this study. Firstly, cueing had little effect on tolerance of larger portion sizes (hypothesis 2). However, it did increase the amount of food (pizza) that the participants planned to consume (confirming hypothesis 1, see Figure 2) and the extent to which this cued food was desired (see Figure 3). In addition, cueing had a significant effect ($p = .02$) on the amount of food that was consumed during the ad-lib. eating phase (cue condition, mean = 173g, $SEM = 7.2$; no-cue condition, mean = 148g, $SEM = 7.2$)

Together, these results are the first of their kind to show that cueing increases the amount of food that people actively plan to eat. Pizza cueing also increased prospective portion size of other foods. This is important, because contrary to previous reports, the effects of cue-exposure appear to be much more general than anticipated.

Figure 2: Mean (S.E.M.) change in prospective portion size (g) [before-after cue/no-cue exposure period] for the cued food (pizza) and the non-cued foods. Significant differences are denoted with an asterisk ($p < 0.05$).
Figure 3: Mean (S.E.M.) change in desire to eat (mm) [before-after cue/no-cue exposure period] the cued food (pizza) and the non-cued foods. Significant differences are denoted with and asterisk ($p<0.05$).

**Evaluation of objective 1**

Objective 1 was met in full. No significant problems were encountered. The data provide a clear indication of the specific effects of cue exposure (at least in a laboratory context). In addition to the original objective (outlined in the proposal), by comparing appetite for both the cued and non-cued foods, this work resolved outstanding issues relating to the effects of food-cue exposure on appetite for non-cued foods. The results from this stage of the project have been submitted to the British Journal of Nutrition and a revised draft is in preparation based on reviewer comments.

**Objective 2: Can laboratory-based observations predict everyday dietary behaviour and BMI?**

**Background**

Building on research addressing objective 1, the second objective was to test the clinical significance of variability in food-cue reactivity. Specifically, the aim was to determine the relationship between BMI and the measures of cue-reactivity that were developed and used in Study 1. In addition, a secondary objective was to consider cue-
reactivity and other measures of individual differences, in particular, binge eating, average everyday food-portion sizes, and dieting behaviour.

Research addressing objective 2

In the first instance it was necessary to generate a participant pool from which to draw age-matched overweight and lean participants. A recruitment website was developed and staff from The University of Bristol (total approx 5,000) were invited to signup online for the study. Adverts were attached to the pay slips of all staff. Approximately 450 members of staff indicated an interest in the study. From these, 50 overweight and 50 normal-weight participants were recruited. Their mean age was 35.2 (SD = 12.71).

As in Experiment 1, participants completed measures of cue reactivity before and after a cueing period. In this experiment all participants were cued with pizza for 1 minute. After providing these measures the participants were given ad-libitum access to pizza. As an addition to the original proposal, a measure of saliva production was taken, again, both before and after cueing. This is potentially important, because it provides an indication of cephalic-phase response – an individual’s physiological preparedness to consume food. Also, as in Experiment 1, appetite was assessed for a range of non-cued foods (before and after cueing). A wider range was selected than in Experiment 1. Again, the objective was to explore the extent to which cueing influences appetite for both the cued food and other non-cued foods.

In this experiment the participants also completed a study-specific health-screening questionnaire. They also completed the impulsivity questionnaire from Eysenck’s Personality Questionnaire (EPQ; (Eysenck & Eysenck, 1975)), the trait food-craving questionnaire (Cepeda-Benito, Gleaves, Williams, & Erath, 2000), the Dutch Eating Behaviour Questionnaire (DEBQ; (Van Strien, Frijters, Vanstaveren, Defoers, & Deurenberg, 1986)), the Revised Restraint Scale (Herman & Polivy, 1975), and the disinhibition subscale of the Three Factors Eating Questionnaire (TFEQ; (Stunkard & Messick, 1985)).

At the end of the procedure the participants also provided an indication of their normal everyday portion sizes. Everyday portion size was measures in two ways. Firstly, participants were shown sets of eight photographs, each set depicting a commonly consumed food (Nelson, Atkinson, & Meyer, 1997). The series of pictures contained portion sizes ranging from the 5th to 95th centile on a distribution of portion sizes observed in The Dietary and Nutritional Survey of British Adults (Gregory, Foster, Tyler, Wiseman, 1990). Participants were asked to use these photographs to indicate the amount of food that they typically consume. In total 15 foods were presented in this way (pasta, cornflakes, sponge pudding, potatoes, baked beans, lasagne, spaghetti bolognaise, chips, cheesecake, roast beef, battered fish, carrots, fruit salad, and quiche). The second approach to measuring everyday portion size is new and was not described in the original proposal. Briefly, 12 different foods were photographed in different portion sizes. A computer program was developed that allows the participant to rapidly select between these images until an appropriate match is made. This approach has many advantages and is described in more detail in the ‘Methods’ section below.
All participants attended a single 60-minute session, held between 11:30 and 14:30. Participants were asked to abstain from eating for a three-hour period before arriving for a test session. On arrival, they provided written consent and completed baseline hunger, fullness and liking visual-analogue scales. Participants then provided a pre-exposure saliva measure. They were asked to fill in pre-exposure hunger, fullness, desire to eat, and craving visual-analogue scales, and then completed an ‘ideal portion-size task’ for the six foods. For each participant, the order of the foods was selected randomly. After the ideal portion-size task, the participants rated their desire to eat the six foods.

The participants were then exposed to the sight and smell of a freshly cooked pizza for one minute. After this period they were again asked to provide a measure of saliva and to rate their post-exposure hunger and fullness. They then provided a second set of desire-to-eat and craving ratings, and then completed the ideal portion-size task once again. Participants were then given free access to 1 ½ pizza (a standard cooked pizza weighs approximately 364 grams; 911 Kcals). The pizza was presented in bite-size pieces rather than in slices. This reduced the extent to which participants were able to remember the amount of pizza they had consumed. After consuming the pizza, participants were asked to fill in hunger and fullness rating scales.

At the end of the session, the participants completed the health-screening questionnaire, the PEQ inventory, familiarity scales and our two ‘everyday portion size tasks.’ They then completed the remaining diet and personality questionnaires, and a measure of height and weight was taken. Finally, the participants completed an awareness questionnaire. This was administered to explore demand characteristics.

Main findings from study 2

Normal and overweight individuals ate a similar amount of pizza and experienced the same degree of change in craving before and after cueing. However, relative to the normal-weight participants, overweight participants salivated significantly more after cue exposure ($p = .03$, see Figure 4), and they experienced a significantly greater increase in their desire to eat pizza ($p = .045$) and their desire to eat other non-cued savoury foods ($p = .035$).

Importantly, cuing also brought about a greater increase in the amount of food that overweight participants planned to consume. Relative to normal-weight participants, cuing increased the ideal portion size of savoury foods ($p = .033$).

In relation to everyday dietary behaviour, the PI found little evidence that overweight individuals choose larger portion sizes or that everyday portion size is related to any of the measures of cue reactivity (desire to eat, salivation, and so on). This issue is discussed in more detail in the ‘future research priorities’ section below. Relationships between cue-reactivity and other personality and dietary measures also failed to reach significance.
Evaluation of objective 2

The aim was to identify differences in food-cue reactivity in overweight and normal-weight participants. In this regard this objective was clearly met. Overweight individuals were more cue-reactive. This was apparent both in subjective ratings (desire to eat), a measure of planned (prospective) portion size, and in a physiological measure that forms part of the cephalic-phase response (salivation). To date, this represents the most comprehensive assessment of the effects of cue exposure in overweight individuals.

- Methods (methodological advances)

In addition to the basic procedural details outlined above, several new methodological advances were made possible by this project. These are outlined below.

(A) Novel measures of ‘ideal’ and ‘everyday’ portion size.

An important feature of this project was the measurement of ‘ideal’ and ‘everyday’ portion size. ‘Ideal’ refers to a participant’s preferred portion size at the time of asking. ‘Everyday’ refers to a measure of the typical or usual portion that a person normally consumes on a day-to-day basis.

In the original application the PI proposed using images of everyday portion sizes using pictures taken from a photographic atlas of food portion sizes (Brunstrom, Mitchell, & Baguley, 2005; Nelson, Atkinson, & Meyer, 2002). This approach is easy to implement.
However, the image quality is typically poor and the number of different images that are presented is limited (8 in total). To address this issue, the PI developed a library of new food pictures. High-quality images were taken, both of pizza, and a range of other non-cued foods. For each food, between 40 and 70 pictures were taken, each showing a different portion size. Pictures were equally spaced (in log units) between 4 and 0.25 times the typical serving size (usually determined by packaging information). By way of example, a set of photographs of pizza is shown in Figure 5.

![Figure 5. Example of picture stimuli used to derive a measure of ideal and everyday pizza-portion size.](image)

Custom software was developed to display the images (written in Visual Basic version 6.0). The participants were shown a picture of a food portion on a 19” LCD monitor. Using left and right arrow keys, they were able to select a portion size that corresponded with their everyday or ideal portion size. Since all of the images were preloaded into the computer, the participant was able to ‘scroll’ through the images very quickly. The position of the food relative to the camera was standardised in all pictures. Therefore, key presses effectively ‘morphed’ the food portion sizes in real time. A ‘screen dump’ of the participant interface is shown below in Figure 6.
Figure 6. Screen dump of ideal-portion size paradigm. Participants use the arrow keys to ‘morph’ larger and smaller portions of food.

More generally, the development of these procedures has proved extremely useful, both in studies at The University of Bristol and in other universities. For example, they are being used by Professor Harry Kissileff to assess clinically obese individuals who are receiving treatment at the New York Obesity Center in St Luke’s Hospital in New York. They are also being used to measure ideal and everyday portion sizes in anorexics attending a treatment programme. This project is conducted in collaboration with Professor Kathy Halmi (and associated team) at the Weill Cornell Medical College (NY State, USA).

(B) Measure of maximum tolerable portion size.

As outlined above, one of the aims in study 1 was to explore the prospect that cue exposure increases the maximum amount of food that a participant is prepared to tolerate. To explore this hypothesis a methodology was developed that uses an adapted version of a ‘method of constant stimuli.’ Participants were shown two pictures of a pizza on a computer screen, one next to the other. One picture corresponded to 40% less than the amount selected using the ideal portion-size procedure outlined above. This was called the ‘standard’ portion.’ The other picture showed a portion size that was always bigger. However, the size of this ‘comparison’ portion changed from trial to trial. On each trial, Participants were told to imagine that they were going to be asked to consume all of one of the two portions (standard and comparison). They were instructed to press the right arrow on the keyboard if they would choose the comparison (right picture) and the left arrow if they would choose the standard (left picture).
It was assumed that very large comparison portions would be rejected in favour of the smaller-than-ideal standard (i.e., they would not be tolerated). Conversely, in response to a small comparison portion, it was anticipated that the comparison would be chosen much more often, especially when the comparison was similar to the ideal prospective portion size. Somewhere between these two extremes, the probability of choosing the standard or the comparison will be equal (both selected 50% of the time). After a sufficient number of trials, it is possible to calculate this ‘point of subjective equality’ (PSE). Here, probit analysis was used to fit a sigmoid function to the associated probability density function. The PSE is important, because it indicates the maximum amount of the comparison that would be tolerated before participants tend to choose the smaller standard. Figure 7 shows some hypothetical data and associated analyses.

![Figure 7](image.png)

Figure 7. The PSE relates to the point at which the standard portion is selected 50% of the time. This provides a measure of maximum tolerable portion size.

To significantly improve the efficiency of the procedure an Adaptive Probit Estimation algorithm (APE) was used (Watt & Andrews, 1981). With this approach, only a subset of the comparison sampling range is tested. APE selects those stimulus levels that maximise the prospect of gaining information about the PSE. The selection of specific comparison values is updated as the participant proceeds through the trials and is based on an analysis of the recent history of responding. Using this approach we were able to derive a PSE within 56 trials. The APE routine and the code for presenting the stimuli were both written in Matlab (version 12). The graphical interface was implemented using Cogent Graphics software (freeware).

This implementation of a method of constant stimuli has also enabled the PI to develop related measures of appetite and everyday portion size. Two empirical papers have been submitted to the journal Appetite (reviews have been received and revised drafts are in preparation). One of these papers reports how the methodology has been used to...
explore everyday portion sizes in undergraduates attending Swansea University. The second paper shows how this approach may be adapted to compare the satiety that different foods are expected to develop. In addition, these empirical paradigms have been incorporated in two research proposals that are currently under consideration. One of these involves an industry sponsor, the other has been submitted to the BBSRC.

- **Results**

The main findings from this project are summarised below:

1. Food-cue exposure influences not only the amount of food that is subsequently consumed, but also the ideal amount of food that is selected before a meal begins (Study 1).

2. Over and above an increase in ideal portion (point 1), food-cue exposure does not increase the amount of food that a person is prepared to tolerate (Study 1).

3. Restrained eaters are show less cue-reactivity than unrestrained eaters (Study 1).

4. Contrary to previous accounts, cue exposure increases appetite for both the cued-food and other non-cued foods that share similar characteristics (e.g., other savoury foods) (Study 1 and Study 2).

5. Overweight participants are more cue-reactive than normal-weight participants (Study 2). This is evident in explicit measures of ideal portion size and ratings of desire to eat, and in a measure of cephalic phase response (saliva volume).

6. Although cueing brought about a significantly greater increase in the ideal portion of overweight individuals, this group provided no indication that they consume larger everyday portions outside the laboratory (Study 2). This point is discussed in more detail in the ‘Future Research Priorities’ section below.

- **Activities**

(C) The research associate on this project (Danielle Ferriday) presented the findings from Experiment 1 at a meeting of the British Feeding and Drinking Group meeting held in Leeds (April 2007). An abstract from this meeting is in press. Ferriday, D. & Brunstrom, J.M. “How does food-cue exposure lead to overeating?” Appetite.

(D) The results from Study 1 and Study 2 were presented at the annual meeting of the North American Association for the Study of Obesity, held in New Orleans in (November 2007). (“I just can’t help myself: Effects of food-cue exposure on overeating). An abstract from this meeting will be published in the journal Obesity.

- **Outputs**
(A) A full paper describing the results of Experiment 1 has been submitted to the British Journal of Nutrition (impact factor 2.7). Based on recent reviewer comments a revised version will be resubmitted in January 2008. A copy of this draft paper is attached to this report (Ferriday, D. & Brunstrom, J.M. (submitted). “How does food-cue exposure lead to larger meal sizes?”).

(B) A full paper describing the results from Experiment 2 is in preparation. This will be submitted to the American Journal of Clinical Nutrition (impact factor 6.6) at the end of January 2008. This work is entitled “Effects of food-cue exposure in overweight and normal-weight individuals.”

- **Impacts**

An account of the impact of methods that were developed is provided above (see ‘Methods’ section). At present the results from this project are not being applied elsewhere and are not being exploited commercially.

- **Future research priorities**

In future, researchers could usefully extend the findings from Study 2. This study provided clear evidence that overweight individuals are more cue-reactive. However, the specific effects of this heightened cue reactivity remain to be resolved. In Study 2 the PI found evidence that overweight participants select relatively larger portions after exposure to a food cue. Nevertheless, this group did not report consuming larger portions outside the laboratory. One possibility that overweight individuals underestimate the portions that they typically consume (Okubo & Sasaki, 2004; Prentice et al., 1986), and this accounts for the apparent discrepancy between their behaviour in the laboratory and their self-report measure of everyday portion size. An alternative possibility is that heightened cue-reactivity leads to both an increase in everyday portion size and an increase in the number of daily eating episodes (i.e., it promotes snacking behaviour). This idea might be tested in future studies using food diaries or some other self-report measure of food frequency.

**References**


