Appetite 84 (2014) 79–87

Contents lists available at ScienceDirect

Appetite

journal homepage: www.elsevier.com/locate/appet

Research report

How food cues can enhance and inhibit motivation to obtain and consume food ☆

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ARTICLE INFO

Article history:
Received 10 July 2014
Received in revised form 24 September 2014
Accepted 25 September 2014
Available online 30 September 2014

Keywords:
Pavlovian-instrumental transfer
Motivation
Associative learning
Food
Craving
Addiction

ABSTRACT

Learning may play an important role in over-eating. One example is Pavlovian-to-instrumental transfer (PIT), whereby reward cues facilitate responding to obtain that reward. Whilst there is increasing research indicating PIT for food in humans, these studies have exclusively tested PIT under instrumental extinction (i.e. when the food is no longer available), which may reduce their ecological validity. To address this, we conducted two experiments exploring PIT for food in humans when tested under instrumental reinforcement. Participants first underwent Pavlovian discrimination training with an auditory cue paired with a chocolate reward (CS+) and another auditory cue unpaired (CS–). In instrumental training participants learnt to press a button to receive the chocolate reward on a VR10 schedule. In the test phase, each CS was presented whilst participants maintained the opportunity to press the button to receive chocolate. In Experiment 1, the PIT test was implemented after up to 20 min of instrumental training (satiation) whereas in Experiment 2 it was implemented after only 4 min of instrumental training. In both experiments there was evidence for differential PIT, but the pattern differed according to the rate of responding at the time of the PIT test. In low baseline responders the CS+ facilitated both button press responding and consumption, whereas in high baseline responders the CS– suppressed responding. These findings suggest that both excitatory and inhibitory associations may be learnt during PIT training and that the expression of these associations depends on motivation levels at the time the cues are encountered. Particularly concerning is that a food-paired cue can elicit increased motivation to obtain and consume food even when the participant is highly satiated and no longer actively seeking food, as this may be one mechanism by which over-consumption is maintained.

Introduction

Obesity and over-eating are pervasive problems world-wide, with more than half of the adult population in OECD countries being overweight and 18% being obese (OECD, 2013). The high rates of obesity come at substantial cost to both individuals and communities. Obesity is associated with increased risk of type 2 diabetes, coronary heart disease, and hypertension, among other conditions and in 1998 was estimated to cost $99 billion dollars in the US alone (Wolf & Colditz, 1998) with projected costs of up to $860 billion by 2030 (Wang, Beydoun, Liang, Caballero, & Kumanyika, 2008).

Whilst there are a multitude of factors that contribute to over-eating, there is increasing recognition of the role that learning processes may play. Consumption of food is inextricably paired with numerous cues such as the sight, smell, and taste of the food as well as signals for its availability, including packaging, logos, and advertisements. Over time, these food cues can acquire the ability to influence eating behaviour in and of themselves. Cue-induced eating is one such example. Here, a cue previously paired with food can elicit increased consumption relative to neutral or unpaired cues both in humans (e.g. Cornell, Rodin, & Weingarten, 1989; Halford, Gillespie, Brown, Pontin, & Dovey, 2004) and animals (e.g. Boggiano, Dorsey, Thomas, & Murdaugh, 2009; Petrovich, Ross, Gallagher, & Holland, 2007). However, one of the most interesting learning processes that may contribute to over-eating is Pavlovian-to-instrumental transfer (PIT) – a process whereby a reward-cue can increase actions directed at obtaining that and other rewards. PIT is particularly interesting because it involves the transfer of food-cue learning (Pavlovian associations) onto goal-directed action to obtain food (instrumental responding). Thus, whereas cue-induced eating concerns how cues influence consumption when food is already present, PIT concerns how cues can lead individuals to actively seek out food. As such, a better understanding of PIT may lead to ways of preventing individuals at risk of obesity from engaging

☆ *Acknowledgements:* This research was supported by Discovery Project DP130103570 provided by the Australian Research Council. We would like to thank Jessica Lee and Nicky Quinn for their help in programming the study and collecting the data and Daniel Forrest for assisting them. We have no conflicts of interest in producing this manuscript.
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http://dx.doi.org/10.1016/j.appet.2014.09.023
0195-6663/

in maladaptive food-seeking behaviours and thereby prevent over-consumption before the food is even present.

There have been numerous animal studies conducted on PIT for both food and other rewards (see Holmes, Marchand, & Coutureau, 2010 for a review). The standard PIT procedure involves three phases: Pavlovian training, instrumental training, and a transfer test (e.g. Colwill & Rescorla, 1988; Estes, 1943; Holland, 2004). In Pavlovian training, one cue (e.g. tone) is paired with a food reward (e.g. food pellet) whilst another cue (e.g. light) is paired with no reward. In the separate instrumental training, the animal learns to make a response (e.g. lever press) in order to obtain the food reward. Then, in the transfer test, each cue is presented whilst the animal has the opportunity to make the instrumental response. PIT occurs when the food-paired cue induces greater instrumental responding than the unpaired cue in the test phase. Further, there is evidence that the PIT effect can be both outcome specific and outcome non-specific, such that a food-paired cue can not only induce greater responding to obtain that specific food reward (specific PIT), but can also induce greater responding to obtain other food rewards (general PIT: Colwill & Rescorla, 1988; Corbit & Balleine, 2005; Delamater, 1996), suggesting two distinct motivational effects.

Whilst most research on PIT has been conducted in animals, there are a growing number of studies demonstrating this phenomenon in humans (e.g. Allman, DeLeon, Cataldo, Holland, & Johnson, 2010; Bray, Rangel, Shimojo, Balleine, & O'Doherty, 2008; Hogarth, 2012; Hogarth & Chase, 2011; Nadler, Delgado, & Delamater, 2011; Prévost, Liljeholm, Tyszka, & O'Doherty, 2012; Rosas, Paredes-Olay, García-Gutiérrez, Espinosa, & Abad, 2010; Talmi, Seymour, Dayan, & Dolan, 2008; Watson, Wiers, Hommel, & de Wit, 2014). Whilst most human PIT studies use symbolic rewards (e.g. points, money), some have also used food rewards (Bray et al., 2008; Lovibond & Colagiuri, 2013; Watson et al., 2014). For example, we recently developed a procedure in which participants first learnt associations between different coloured lights and a chocolate reward and then were separately trained to press a button to receive the same chocolate reward (Lovibond & Colagiuri, 2013). In the transfer test, we found a strong PIT effect whereby presentation of the chocolate-paired cue led to a much higher rate of button pressing than the unpaired cue. An important feature of this procedure was that the participants consumed the chocolate rewards throughout the experiment and were free to either respond or not respond during the transfer test. This seems to indicate a genuine motivational effect induced when using a natural-high value food reward, which may explain how food cues contribute to over-consumption.

However, one potential limitation in terms of the applicability of existing PIT research to eating behaviour is that the transfer test is almost always carried out under instrumental extinction, i.e. when the instrumental response no longer leads to food. Whilst this is an intentional design feature of these studies aimed at reducing any ceiling effects that could occur if responding during the test was too high, whereby no facilitation could be observed, it does make it difficult to determine whether PIT can induce food seeking when the food is still available, as is the case outside of the laboratory. To date, only a handful of studies have investigated PIT when tested under instrumental reinforcement and these have been conducted exclusively in animals. The results of these studies have been mixed, with some finding that food-paired cues enhance instrumental responding (Edgar, Hall, & Pearce, 1981; Hamm & Meltzer, 1977; Meltzer & Brahlek, 1970) and others finding that food-paired cues actually inhibit responding (Azrin & Hake, 1939; Lovibond, 1981; Soltysik, Konorski, Holownia, & Rentoul, 1976). Thus, it is currently unclear whether PIT can be observed in humans when tested under more naturalistic conditions in which the response is reinforced and whether any such effect is facilitatory or inhibitory. Testing under reinforcement may be particularly important given that outside of the laboratory, food cues are likely to be most often encountered when the food is still available to obtain, not under extinction. An example would be seeing a pizza advertisement when a viewer knows he or she can order pizza and have it delivered soon after. By contrast, testing under extinction would be more akin to seeing a pizza advertisement after multiple attempts to order pizza without it being delivered.

To address this gap, we conducted two experiments using a standard PIT design with a chocolate reward, but with the transfer test conducted under instrumental reinforcement, such that the participants could still earn chocolate during the test phase. In the first experiment, we allowed a natural reduction in responding due to satiation before implementing the PIT test, whereas in the second experiment we implemented the PIT test fairly soon into instrumental training, when satiation was lower. If there is no PIT effect or an inhibitory one when tested under reinforcement, then it would seem unlikely that PIT could contribute to over-consumption of food. On the other hand, if PIT does produce facilitation under these circumstances, then it seems quite likely that it could be an important mechanism in the maintenance of maladaptive eating behaviours and that these cues could serve as points of intervention. To our knowledge, this is the first study investigating PIT under instrumental reinforcement in humans.

Experiment 1

The first experiment used a very similar design to our previous work in this area involving a chocolate reward (Lovibond & Colagiuri, 2013). The critical difference was that the transfer test was conducted under instrumental reinforcement. To attempt to avoid potential ceiling effects, in Experiment 1, we implemented the transfer test after a natural reduction in responding (4 min no response) or after 20 min cumulative time irrespective of response rate, which are comparable parameters to those used in animal studies (e.g. Lovibond, 1981).

Methods

Participants

Eighty-one first year undergraduates from the University of Sydney participated. Fifty-six were first year psychology students who participated in return for partial course credit whilst the remaining 25 were recruited on a university volunteer website and were reimbursed AUD$15 for their participation. In both cases, the advertisement described the study broadly as investigating responses to eating chocolate and associated stimuli, and participants self-selected to enrol in the study. Overall, there were 48 females (64.9%) and participants had a mean age of 19.3 (SD = 1.5). Participants were asked to abstain from eating any food for 3 h prior to the experiment and from eating chocolate for 24 h prior to the experiment. In order to confirm this, two questions were included in the demographic questionnaire asking participants to report the last time they had eaten any food and the last time they had eaten chocolate, without any reminder of the eligibility criteria. Participants were excluded if they were currently dieting. All study procedures were approved by the University of New South Wales Human Research Ethics Committee (HREC) and ratified by the University of Sydney HREC.

Materials

Participants were seated at a desk in a 2 m × 2 m testing cubicle, facing a 61 cm computer monitor. A keyboard was placed immediately in front of the participant and had every key removed except for the space bar. On the desk to the left of the monitor was a Med Associates M&M's dispenser Model ENV-702 on a pedestal mount, inside a 210 mm × 170 mm × 330 mm sound attenuating plywood box. A clear 20 mm diameter plastic tube delivered individual M&M