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Response inhibition training and measures of explicit and implicit food valuation

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The overvaluation of energy-dense foods is a key contributor to unhealthy eating behaviour, identifying it as a key target for therapeutic interventions. A growing literature has shown that by consistently associating specific food items with the inhibition of a motor response (i.e. stopping), the evaluations of these stimuli can be reduced after training. In this brief review, we focus on measures used to capture food valuation following such training interventions. Evidence for the food *devaluation effect* has primarily stemmed from studies that employ explicit measures such as ratings of food attractiveness or taste, and implicit measures, such as the implicit association test, which have yielded mixed findings. Although promising, our understanding of the utility of implicit measures in studies of eating behaviour is relatively sparse, and we offer recommendations for the use of explicit and implicit measures in future research.

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Introduction

Many environments are characterised as 'obesogenic' due to an increase in the availability and promotion of processed energy-dense foods that are high in fat, sugar and/or salt content [28,47,59]. The realisation of these environmental factors has prompted a major effort towards understanding how the perception and valuation of food cues (e.g. sight, smell) shapes the development and maintenance of unhealthy eating behaviours, such as overeating. If we assume that an overvaluation of intrinsically rewarding foods is a key determinant of eating behaviours [4,20,48,56], then we can further posit that reducing the affective value of specific foods using psychological interventions should have a therapeutic potential (see [37]). One prominent behavioural intervention that has been shown to have positive outcomes for eating behaviours is response inhibition training, in which individuals are trained to stop or restrain their motor responses towards specific food items, resulting in subsequent devaluation of those items [17,36,60]. In this review, we focus on the measures that have been used in the literature to capture food valuation in the laboratory.

Defining valuation in food research

There is not one agreed definition on food valuation, but leading theoretical frameworks share the notion that eating behaviour can often be driven by impulsive responses, such as a strong positive affective reaction and tendency to approach a food cue in the environment even in the absence of conscious awareness (e.g. 'automatic' processes in dual-process models [30,61], 'liking' in the incentive-sensitisation theory [12,54]). Although there is evidence for cue-evoked affective reactions in the brain's reward system (e.g. [11,13]) and these concepts have been studied extensively in the laboratory (e.g. see reviews by [53,62]), the definition and consequently the measurement of food valuation remains a controversial theoretical and empirical problem. In this review, we focus on valuation from the perspective of explicit evaluative judgements on the taste and attractiveness of food items (explicit), affective reactions and implicit attitudes towards target food categories.

Response inhibition training for eating behaviours

In recent years, there has been considerable empirical attention on the potential efficacy of food-specific inhibitory control training as an adjunct intervention for dietary behaviour change [37]. Experimental paradigms such as the stop-signal task [42,44] and go/no-go task [22,50] have been adapted to train individuals to consistently associate target stimuli, such as energy-dense foods, with the inhibition of a motor response. For example, a go/no-go training task, which has been shown to lead to replicable small-to-medium food devaluation effects (e.g. [16,17]), requires participants to press a key when they perceive a specific visual or auditory cue and refrain from pressing the same key when another cue appears (e.g. low-pitch or high-pitch tone). In this type of response inhibition training, the stimulus-response pairings are manipulated so that responding or not responding is consistently associated with target food items ('go' and 'no-go' foods, respectively). Research has shown that no-go foods are evaluated less positively after training (relative to baseline) compared with both go foods and items that were never presented during training (e.g. [16–18]).[3]

This *no-go devaluation effect* can potentially explain the findings for dietary behaviour change after training, as, for example, an observed reduction in individuals' impulsive food choices for no-go foods (e.g. [15,64,66,67]), food intake (e.g. [34,40,43,52]; also see [5,36]) and even positive weight loss outcomes (e.g. [43,49,69]). Stimulus devaluation may occur as a result of conflict resolution during training because the need to inhibit a response is incompatible with a tendency to approach appetitive stimuli (Behaviour Stimulus Interaction theory [68]) or hard-wired connections between response inhibition (stopping) and avoidance/aversion [46,70]. Under both accounts, negative effect is attached to the no-go foods during training, causing an overall stimulus devaluation that could be captured afterwards using either explicit or implicit measures.

Explicit and implicit measures of food valuation

Most studies that have provided evidence for the no-go devaluation effect have presented participants with explicit rating scales and the operationalisation of value is varied. In this review, we focus on explicit measures that can capture the affective food evaluations (see Table 1). *Explicit measures* that have been used to test for training-induced food devaluation effects include but are not limited to Likert and Visual Analogue Scales that ask participants to rate the stimuli on their *attractiveness* [16–18] or *appeal* [58] as well as both attractiveness and *liking/taste* ratings (e.g. [43,66]; also see Study 4 in [2]).

There are also several *implicit measures* in psychology research that could be used to assess food valuation (see review by [26]), but the most commonly employed measure in the training literature is the *Implicit Association Test* (IAT [27]). For example, Adams et al. [3] employed two unipolar single-category IATs (SC-IAT [38]) to measure participants' positive and negative implicit attitudes towards chocolate after training and did not observe reliable differences between their experimental and control groups (Study 1). The SC-IAT can measure the strength of evaluative associations between one attitude object or concept (e.g. chocolate) and an attribute dimension (e.g. *pleasant* in the positive SC-IAT), while the IAT can assess the relative strength of evaluations for an attitude object/concept over another (e.g. high-calorie vs. low-calorie foods). Although the number of studies employing variants of the IAT is small[4] (also see Table 1), and studies using explicit measures have provided ample evidence for a no-go devaluation effect, a meta-analysis showed that devaluation is not reliably observed with IAT variants (food and alcohol studies [36]).

Another implicit measure that could be used to assess changes in food valuation after training is the *affective priming paradigm* (APP [24,25,29,39]). This paradigm has been successfully applied as a measure of food evaluation [41,55,65,71] and there is preliminary evidence to suggest its potential use in capturing devaluation effects in a training context [63]. A common variant of the APP is the evaluative categorisation task in which participants must categorise words (targets) according to their evaluative connotation (positive or negative) as quickly and as accurately as possible, without paying attention to the food stimuli that appear shortly before (< 300 ms, see [24]). In contrast to the IAT, participants' responses do not involve the evaluative categorisation of the food stimuli, but only semantically unrelated words. When the valence of the words matches that of the food prime (congruent trial), participants tend to be quicker to respond compared with when their stimulus (i.e. food) evaluation contrasts with the connotation of the word (incongruent trial). This priming effect can occur as a result of response facilitation/competition [24,73]. However, it is still not clear whether the APP is sensitive to the strength of food evaluations [41] or whether observed effects are influenced by affective (e.g. liking of taste) or cognitive components (e.g. health concerns, caloric content and cost of purchase) of food attitudes, which often interact to predict eating behaviours [1,8,23,65,71].

Methodological considerations and implications

Explicit evaluations of foods in training studies could potentially be affected by the same limitations as any other self-report measures, such as demand characteristics and strategic response bias (see [51]), but this should hold true for any assessment that can make par-

[3] Some studies have also observed a 'go valuation effect' in which foods paired with go trials are evaluated more positively compared with other foods (e.g. see [17,18]), which could have therapeutic applications when the go foods are 'healthier' options or alternatives. Increasing the evaluation and/or choices for specific foods has also been investigated using other training paradigms (e.g. cued-approach training [74]).

[4] In this brief review, we have not included studies that used the IAT with alcohol-related stimuli after training (e.g. Bowley et al., 2013, [32,33]). Similarly we have not added studies that employed the IAT for other purposes (e.g. measuring go/stop associations [34]). Other studies have operationalised 'value' as willingness to pay (i.e. how much you would bid to get the food, see [74]).

Table 1

Training studies that have measured ‘explicit’ and ‘implicit’ food valuation.

Study	Training protocol	Food stimuli	Valuation outcomes	Effects of interest
	Explicit measures			
[66]	Single session of GNG with visual cues (letters)	Fixed set of ‘palatable’ foods from previous work	Average of both ratings (Likert): *Attractiveness* (1 = not at all attractive; 7 = very attractive) *Palatability* (1 = not at all tasty; 9 = very tasty)	Significant decrease in evaluations for no-go foods in a high-appetite condition.
[17] (Expt 1)	Single session of GNG with auditory cues	Set of ‘palatable’ foods tailored to individual attractiveness ratings (including fruits, veg, etc.)	*Attractiveness* slider (–100 = not at all; 100 = very much) ‘How attractive does this food item look to you?’	Devaluation from pre- to post training was significantly lower (i.e. stronger) for no-go foods compared with both go and untrained foods.
[43]	Multiple sessions of GNG with visual cue (bold central rectangle)	Set of most frequently consumed snacks (high-energy density)	*Liking of taste*: How much they liked the taste *Attractiveness*: How attractive the image looked (without considering the taste) 100-mm VAS (‘not at all’ to ‘very much’)	Significant reduction in liking in the active compared with the control group for no-go foods. Attractiveness ratings decreased for no-go foods but there were no significant group differences.
[58] (Study 1)	Single session of GNG with visual cues (letters)	Fixed set of ‘attractive’ foods (including beverages)	*Appeal* (1 = not at all appealing, 9 = extremely appealing)	Significant devaluation for no-go foods compared with both go and untrained foods immediately after training but *not* after a 10-min delay.
	Implicit measures			
[3] (Study 1)	Single session of SST with visual signal (bold central rectangle) at variable delays	Fixed set of chocolate images	*Unipolar SC-IATs* for positive and negative implicit attitudes towards chocolate stimuli	No significant interaction between training groups (stop vs. control) and SC-IAT scores.
Forman et al. 2019	Multiple sessions of gamified GNG with visual cues and variable latency limits	Set of sweets tailored to individual consumption frequency	*IAT* for implicit preferences towards sweets with affective categories 'good' + 'bad' and target food categories healthy + sweet	No significant differences from pre- to post training.
[63] (Expt 1)	Single session of GNG adapted from [17]	Set of energy-dense foods tailored to individual liking ratings	*APP* for differences in affective reactions towards trained and untrained foods	The RT priming effect for no-go foods was significantly reduced compared with the effect for go and untrained foods.

Note. Additional details regarding the study protocols (e.g. multiple training groups, proportions of go and no-go trials, sample characteristics etc.) are not outlined here as they go beyond the purpose of this review. For multi-experiment publications, we have included only selected studies as valuation measures do not differ (e.g. [17,58]). GNG: Go/no-go training; SST; stop-signal training task; S-R: stimulus response; Expt: experiment.

ticipants aware of the study aims (i.e. training or task aimed at changing food preferences or liking). Even outside of a training context, this is an important methodological consideration for studies exploring food valuation as it may be especially sensitive to social desirability (e.g. rating energy-dense foods very highly when an individual aims to reduce their consumption frequency). Researchers could collect more data on participants' awareness of stimulus-response associations after training, as, for example, through a memory recall task (e.g. see [18]). Another potential issue with explicit measures is that food evaluations are captured by various scales that can differ in their instructions and wording (e.g. how attractive an image is vs. how tasty a food is, see Table 1), and it remains unclear whether all measures of explicit valuations in this context tap into the same construct.

There are currently not enough studies in the literature that have employed different implicit measures to capture the no-go devaluation effect, but there are certain methodological considerations that could explain the mixed findings in food and alcohol research (meta-analysis findings in [36]). For instance, the SC-IAT requires participants to explicitly categorise stimuli according to specific pairs of labels and attribute categories (e.g. 'chocolate and pleasant' vs. 'neutral' in the positive SC-IAT). This unipolar approach offers the benefits of examining food-specific attitudes that may be the best option for investigating training effects (i.e. trained or untrained chocolate stimuli) as opposed to relative effects using the original IAT structure (e.g. high- vs. low-calorie foods, see comparison of relative and non-relative IAT findings in [35]). However, we should note that any IAT variants can potentially be affected by certain parameters, depending on the participants' pattern of responding. For example, the explicit categorisation of stimuli could result in participants becoming aware of the task aims and responding strategically or even evaluating the category labels instead of the presented stimuli [21,24]. Alternatives to the IAT that do not require explicit judgements on trained stimuli may need to be explored further for their reliability in training studies (e.g. APP or similar tasks, as in [72]). Another important issue to consider is whether the validity of the IAT is dependent on the construct of interest (i.e. food value) and whether it is sensitive enough to capture the strength of valuation towards specific food categories (e.g. no-go vs. go) as opposed to more distinct group differences for overall food attitudes (e.g. individuals who prefer to eat lower-calorie snacks compared with those who do not, see [57]).

A key assumption of implicit measures is that they can tap into participants' automatic affective evaluations because tasks have strict time constraints that reduce the likelihood of controlled/conscious processing [29]. If at the core of such measures is the premise that reaction times can reflect changes in implicit (food) valuation,[5] then we should also consider another potential methodological issue. One of the proposed mechanisms of action behind training effects is the formation of learned associations between specific stimuli and response inhibition, which can be observed when participants are slower to respond to the same stimuli in a reversed-contingency task after training [9,10,14]. This stimulus-stop association can affect reaction times in post-training implicit measures as participants may be slower to respond to no-go items, irrespective of the task manipulation/type of trial (as discussed in [17]) and thus independently of any effects of the training on devaluation. If response speed is affected for all types of trials (e.g. in the congruent and incongruent trials of the APP), then we should still observe effects based on reaction time *differences* between congruent versus incongruent trials (i.e. the priming effect), but the extent to which stimulus-stop associations and devaluation effects might interact to obscure or distort such priming effects is not well understood and should be taken into account when interpreting findings.

A crucial consideration for future research is what the expected relationship between explicit and implicit measures of food valuation should be in this training context, as in most cases, there may not need to be a distinction between the constructs at all (also see [24]). For example, when food value is not determined by underlying conflicts in dietary goals and/or eating disorder pathology, we would not expect a non-trivial difference between explicit and implicit outcomes. However, there is still empirical uncertainty regarding this explicit–implicit dissociation (e.g. see [7,19,31]). It would be of greater importance to identify the predictive validity of measures that are used to capture food valuation — that is, which measure can best predict real-world eating behaviours (e.g. see Ecological Monetary Assessment study that only reported weak evidence for the predictive utility of explicit measures for snacking behaviour, but not food choice or implicit preference tasks [45]) — and the construct validity of such measures as they relate to our current theoretical accounts of response inhibition training mechanisms.

Conclusion

Food valuation in response inhibition training studies has been examined using both explicit and implicit measures and there is evidence to suggest that a devaluation effect

[5] While the terms 'explicit' and 'implicit' can be used to describe the employed measures, this distinction may not always refer to psychological constructs under investigation [24]. If a lack of awareness is not formally tested, we cannot infer with certainty that measures such as the IAT or APP tap into automatic/unconscious processes. Explicit measures *directly* assess food evaluations, whereas implicit measures achieve this *indirectly* through reaction time and/or accuracy metrics (i.e. also referred to as direct and indirect measures).

is observed primarily when participants self-report their evaluations after training. Understanding the mechanisms of action behind devaluation effects will require more research focusing on automatic processes and implicit attitudes. We offer the following specific recommendations. First, given that implicit processes are considered critical to eating behaviours (see [6,61]), future research should investigate whether training-induced devaluation can be reliably observed across a range of implicit measures and, conversely, how implicit interventions influence eating behaviour outcomes such as food consumption, impulsive choices and weight loss. Second, due to the variability in methodology, smaller number of studies and potential limitations of certain implicit measures, we recommend that researchers take into account the employed methodology (e.g. IAT variants) in interpreting existing findings and in designing novel studies or replications of prominent effects in the literature. Finally, future research using implicit measures should also clarify the relationship between the explicit and implicit components of food evaluations, for instance, mapping the predictive relationship between choices/ratings and priming effects and how this is moderated by different variables (e.g. individual differences in dietary restraint) and health contexts (e.g. eating disorders).

Conflict of interest statement

The authors declare no competing interests.

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