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# Motivating operations in appetite research

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**Abstract**

Appetite research frequently employs principles derived from behaviour analysis. However, it has yet to utilise the more recent theoretical advances in this field. This paper describes the concept of the *motivating operation* (MO)—a behaviour analytic formulation of motivation. An MO is an environmental event that (a) establishes or abolishes the reinforcing or punishing effect of another event and (b) evokes or abates behaviours associated with that event. The paper describes both unconditioned and conditioned MOs and the ways in which they may help account for a variety of eating behaviours. It then goes on to highlight the main ways in which the MO account differs from other theories of motivation employed in appetite research. These relate to (1) the ways in which they account for non-regulatory feeding, (2) the extent to which they address cognitive variables and (3) their underlying philosophical assumptions and subsequent relation to intervention.


*Keywords:* Motivating operations; Establishing operations; Motivation; Behaviour analysis; Incentive learning theory; Conditioned modulatory stimulus model; Two factor theory; Food; Intervention; Non-regulatory feeding

Principles derived from the behaviour analytic tradition are frequently employed in the field of appetite research. In particular, operant and respondent conditioning have been used to account for findings in areas ranging from taste preferences and aversions (Rozin & Zellner, 1985) to binge-eating (Jansen, 1998; Waters, Hill, & Waller, 2001) and chocolate craving (Gibson & Desmond, 1999). In recent years there have been a number of exciting new theoretical advances in the field of behaviour analysis (e.g. see Roche, 1999). Among these is the concept of the *motivating operation* (MO); a behaviour analytic formulation of motivation developed by Michael (1982,1993,2000; Laraway, Snycerski, Michael & Eilon, 2003). This concept has made an important contribution to both basic and applied behaviour analysis, stimulating new research and leading to innovative intervention strategies (see Iwata, Smith & Michael, 2000). Given the use of behaviour analytic principles in appetite research, it seems likely that MOs could also prove beneficial to the field.

This paper begins by highlighting some of these potential benefits. It then goes on to describe the concept of the MO, along with Michael's taxonomy of unconditioned and conditioned MOs. Finally, it compares the MO concept with theories of motivation currently employed in appetite research.

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## Why motivating operations?

The MO account shares many theoretical elements with existing approaches to motivation, as indeed has to be the case given the extent to which existing approaches have been corroborated. However, the advantages of the MO account are as follows:

1. A large part of the MO account is concerned with conditioned motivational variables. These have direct implications for non-regulatory feeding (i.e. feeding in the absence of energy depletion). Whilst other theories may touch upon non-regulatory feeding, they tend not to address it in detail. However, since human feeding behaviours frequently occur in the absence of energy depletion, it is an issue that is critical to our understanding of human appetite. The MO approach can account for a variety of feeding behaviours in this domain and also leads to specific, testable hypotheses.
2. The MO approach uses the same principles to account for both 'cognitive' and 'non-cognitive' influences on

feeding. This provides both parsimony and scope with MOs being just as applicable to health promotion and advertising as they are to deprivation and dehydration. In contrast, cognitive variables tend not to be addressed by other theories of motivation but, given the considerable influence of cognition on human feeding, are critical for any complete account.

3. The MO account is designed specifically to facilitate intervention as it is formulated in terms of environmental variables that can be manipulated directly. Accordingly, findings derived using the MO account can be more immediately applied to behaviour change. This issue would seem to be important in a field where so much of the research is applied.

These points will be examined in more detail later on.

## What are motivating operations?

The topic of motivation was considered in early texts on behaviour analysis (Skinner, 1938; Keller & Schoenfeld, 1950). However, Michael (1993) argued that interest in motivation gradually declined to the extent that motivative variables were frequently ignored or misclassified. In an attempt to address these problems he wrote a series of papers elaborating and refining the concept of the MO[1] which he used to refer to variables with motivational properties (Laraway et al., 2003; Michael, 1982,1993,2000). Michael (1982) chose the term 'operation' to emphasise their environmental nature and in a later paper (Michael, 1993) defined an MO as:

…an environmental event, operation, or stimulus condition that affects an organism by momentarily altering (a) the reinforcing effectiveness of other events and (b) the frequency of occurrence of that part of the organism's repertoire relevant to those events and consequences (p. 192).

Thus an MO has two main effects; first, it establishes or abolishes the reinforcing (or punishing) effect of another event (the *value-altering effect*[2]) and second, it evokes (or abates) behaviours associated with that event (the *behaviour-altering effect*). The term *establishing operation* (EO) is used by Michael to refer to MOs that *increase* the reinforcing or punishing effectiveness of other events and *evoke* behaviours associated with those events. For example, food deprivation both increases the reinforcing effectiveness of eating and evokes behaviours that have previously led to eating. An individual who has not eaten for some time may therefore experience more pleasure when eating, may eat a greater quantity of food and may eat more rapidly. He or she is also more likely to engage in behaviours that have previously resulted in eating, such as preparing food or seeking a restaurant.

In describing the evocative effects of the EO, Michael (1993) is careful to distinguish them from the evocative effects of the discriminative stimulus (SD). The SD evokes behaviour as a result of a history of being reliably paired with an increased availability of a particular reinforcer. Hence a restaurant sign may act as an SD for food since in the past its presence has been paired with the availability of food. As a result, a restaurant sign may evoke behaviours associated with obtaining food, such as entering the restaurant and asking for a table. However, in contrast to an EO, an SD does not alter the value of the reinforcer. Thus whilst food deprivation (an EO), increases the value of food, a restaurant sign (the SD) does not. To put it in non-behavioural terms, an EO determines how much you want something, whilst an SD signals its availability.

The term *abolishing operation* (AO) is used by Michael (1993) to refer to MOs that have the reverse effect to EOs. In other words, they *reduce* the efficacy of other events or stimuli to function as reinforcers or punishers and *reduce* the frequency or likelihood of behaviours that have previously led to those consequences. For example, food consumption both reduces the reinforcing effectiveness of eating and reduces the frequency of behaviours that have previously led to eating. Thus a satiated individual will find eating less pleasurable. If they do eat, they are likely to do so relatively slowly and to consume a relatively small amount of food. They are also less likely to engage in behaviours that have previously resulted in eating, such as food preparation.

In addition to evoking (or abating) behaviour directly, MOs also give rise to their behaviour-altering effects by influencing the evocative strength of relevant SDs. In other words, MOs make individuals more or less responsive to cues that have previously been associated with the availability of the relevant reinforcer (or punisher). For example, an individual who is food deprived is likely to be highly responsive to cues associated with eating, such as the sight of food in a café window or the smell of food coming from a restaurant. On such occasions, these cues will be particularly effective in evoking behaviours that have previously led to eating, such as entering a restaurant and asking to see a menu.

Michael (2000) states that the value-altering and behaviour-altering effects of MOs occur 'simultaneously and independently' (p. 403). He illustrates this with the example of food deprivation. Here the organism's rate of

[1] Michael originally used the term *establishing operations* as a short hand for motivative variables that had either establishing or abolishing effects. He has since suggested that this be replaced with the term *motivating operations* (Laraway et al., 2003). Thus in the present paper, the term motivating operations is sometimes used to refer to events that were originally described by Michael as establishing operations.

[2] The use of the word 'value' should be seen simply as a shorthand way of referring to the reinforcing or punishing effects of an event. Thus 'value-altering effect' is a technical term with a specific definition and should not be confused with other meanings associated with the word 'value'.

food seeking behaviour increases prior to any contact with food. As such, one cannot attribute this change to the increased efficacy of food as a reinforcer. However, upon obtaining food the organism may display further increases in food seeking behaviours due to the food functioning as a highly effective reinforcer.

This distinction between value-altering and behaviour-altering effects is important since it means that MOs can account for findings in the appetite literature where simple operant conditioning processes cannot. For example, in a standard reinforcer devalution procedure (e.g. Adams & Dickinson, 1981; Colwill & Rescorla, 1985) a rat is trained to press a lever for food. The food is then 'devalued', either by conditioning an aversion to it (for example by injecting lithium chloride in order to bring about gastric illness), or by inducing satiation (for example by providing free access to the food). In both instances the devalution procedure takes place without the animal performing the instrumental response (i.e. without the animal pressing the lever in order to receive the food). Instrumental responding for food (i.e. rate of lever press) is then tested again in extinction. The results of these studies show that the devalution procedure brings about a reduction in responding for food (i.e. a reduced rate of lever pressing) even though the animal has not been reinforced for the response either during or following the devaluation procedure. The reduction in responding cannot therefore be explained by the reduced reinforcing properties of the food and thus cannot be accounted for in terms of operant conditioning. However, as noted above, the MO account distinguishes between the value-altering and behaviour-altering effects of MOs, with the latter evoking or abating behaviour directly by influencing the strength of relevant SDs. This in turn makes animals more or less responsive to cues that have been previously associated with the availability of the relevant reinforcer. Thus the devaluation procedure functions as an abolishing operation, that reduces the evocative strength of the SDs associated with food (e.g. the lever) which in turn reduces instrumental responding for food (e.g. the lever press response), without the need for contact with food. This concept of behaviour-altering effects is consistent with research on Pavlovian incentive processes that shows that conditioned stimuli can acquire the ability to activate motivational processes through their association with a reward (e.g. Bindra, 1974; Colwill & Motzkin, 1994; Lovibond, 1983; Rescorla & Solomon, 1967, see also Dickinson & Balleine, 1994).

Michael does not explore the extent of the independence between value-altering and behaviour-altering effects. However, it is possible that the strength of an MO's value-altering effects could be independent from the strength of its behaviour-altering effects. Moreover, an MO might have value-altering effects in the absence of behaviour-altering effects or vice versa. Such a view is consistent with neurological research relating to 'liking' for food rewards and 'wanting' food rewards. Liking is described as the sensory pleasure of eating whilst wanting is described as the disposition to eat (Berridge, 1995). The former is measured by assessing the organism's affective reactions to food and the latter by measuring actions that are performed in order to obtain food. Thus behaviours associated with liking and wanting overlap with those associated with value-altering and behaviour-altering effects respectively. Research indicates that electrical stimulation of the brain, brain lesions or the administration of drugs can influence liking and wanting independently of each other (Berridge, 1995). However, further research would be needed to determine whether it is also possible to independently manipulate liking and wanting or value-altering and behaviour-altering effects using variables that occur more frequently in everyday life.

Michael (1993) described four types of MOs; unconditioned motivating operations (UMOs), and three types of conditioned motivating operations (CMOs). In the sections that follow, each of these will be described in turn with examples of the ways in which they are relevant to appetite research.

### *Unconditioned motivating operations*

Unconditioned establishing operations (UEOs) include deprivation of food, water, sleep and sexual reinforcement. They are EOs that increase the reinforcing (or punishing) effectiveness of unconditioned reinforcers (or punishers) without requiring any learning history (Michael, 1993). For example, dehydration will increase the reinforcing value of water even amongst newborns (Bruno, 1981). However, according to Michael (1993), many of the behaviours that UEOs come to evoke are likely to be learned. Thus whilst dehydration increases the reinforcing value of water, the individual still needs to learn to perform those behaviours that reliably result in water. Once these behaviours are learnt, they will then be evoked by dehydration. This account is consistent with research showing that rat pups fail to exhibit water seeking behaviours when dehydrated unless they have had prior experience of encountering and consuming water in a deprived state (Changizi, McGehee, & Hall, 2002; Myers & Hall, 2001). Since pups as young as 3 days of age will show an increased intake of fluids when dehydrated (Bruno, 1981), this absence of seeking behaviour is clearly not because water is failing to function as an effective reinforcer. Such findings have also been shown to apply to rats' food seeking behaviours (Changizi et al., 2002).

Although the clearest examples of UEOs for food and water are probably deprivation, research suggests that other events may also function in this way. In particular, it is likely that salt consumption and exercise function as UEOs for water (Durlach, Elliman, & Rogers, 2002; King, Appleton, Rogers, & Blundell, 1999). There is also evidence to suggest that certain events function as

UEOs for specific foods and nutrients. For example, exercise is likely to be a UEO for salt (Leshem, Abutbul, & Eilon, 1999; Wald & Leshem, 2003) and deprivation of particular nutrients (e.g. salt) and macronutrients (e.g. protein) a UEO for those nutrients/macronutrients (e.g. Gibson, Wainwright, & Booth, 1995, see also Booth, 1985,1990).

If deprivation is a UEO for food and water consumption, then satiation will function as an unconditioned abolishing operation (UAO). In other words, food satiation will both reduce the efficacy of food as a reinforcer and abate behaviours that have previously led to food. Reductions in the reinforcing value of food will occur from birth, but many of the responses associated with the UAO will be learnt. This is illustrated in a study by Balleine (1992). After training food-deprived rats to press a lever for food pellets, he showed that when subsequently tested in a non-deprived state, under extinction conditions, they failed to show a reduction in their frequency of lever presses. Only when they were exposed to the food pellets in the non-deprived state did they learn to reduce the frequency of their lever press responses.

Research indicates that food satiation also acts as a UAO at the level of individual flavours, textures and other sensory characteristics. As a result, consumption of a particular food will function as a UAO for that food. This effect, termed sensory-specific satiety, occurs in both humans and animals and is present in newly weaned infants (Rolls, 1986). It is possible that other events also function as UAOs for food. For example, exercise has been shown to result in immediate (though short-lived) reductions in hunger (King, Tremblay, & Blundell, 1997).

Although Michael (1993) described the effects of MOs as ‘momentary’, others have drawn attention to the fact that it is possible for MOs to have their effects over periods of days, weeks, or even years (Dougher & Hackbert, 2000; Olson & Austin, 2001; Poling, 2001). This is true of a range of MOs relevant to appetite research. For example, food deprivation may be restricted to a few hours or may extend over a period of years. Consequently, the value- and behaviour-altering effects of food deprivation may be present for a relatively short duration or on an almost permanent (albeit reversible) basis. Such an analysis may in part help account for differences between those who consciously restrict their food intake (*restrained eaters*) and those who do not (*unrestrained eaters*). Compared to unrestrained eaters, restrained eaters have been shown to eat more after exposure to the sight or smell of food (Fedoroff, Polivy, & Herman, 1997; Fedoroff, Polivy, & Herman, 2003; Jansen & Van den Hout, 1991; Rogers, & Hill, 1989) or after eating an appetizer (Jansen, 1994). Thus dietary restraint may be viewed as an EO for food that tends to be in effect over a long period of time. Accordingly, it heightens the evocative effect of relevant SDs (hence the enhanced reactivity to the sight and smell of food) and increases the reinforcing value of the food itself (resulting in overeating after exposure to an appetizer).[3]

### *Conditioned motivating operations*

Conditioned motivating operations (CMOs) function in the same way as UMOs; they alter the efficacy of an event or stimuli to function as a reinforcer (or punisher) and they evoke (or abate) behaviours associated with that event. Unlike UMOs however, CMOs are acquired as a result of the individual’s learning history. In other words, they are events that were originally neutral in relation to a particular reinforcer (or punisher), but have acquired motivative functions as a result of their association with either UMOs or previously established CMOs. Michael (1993) describes three types of CMOs; surrogate CMOs, reflexive CMOs and transitive CMOs.

#### *Surrogate conditioned motivating operations*

Surrogate CMOs acquire their motivative effects as a result of being paired with another MO and produce effects that are identical to those of the original MO. For example, a reduction in body temperature is a UEO for an increase in body temperature (Michael, 1993). In other words, getting cold tends to make us engage in behaviours that will warm us up, such as putting on another jumper or turning up the heating. Stimuli that are reliably correlated with a decrease in body temperature may therefore function as surrogate CEOs for a body temperature increase. For instance, someone driving up a mountain may start to encounter snow and ice. Snow and ice tend to be correlated with a decrease in body temperature and may therefore function as a surrogate CEO for increases in body temperature. This may result in the driver turning up the heating in the car, even though the temperature inside the car may not have altered.[4]

The extent to which surrogate CEOs for food and water arise by being paired with food and water deprivation is unclear. Michael (1993) argued that surrogate CEOs are more likely to occur when paired with UEOs that have a relatively rapid onset, such as changes in temperature. He pointed out that food and water deprivation tend to occur gradually which may make it more difficult for them to become reliably correlated with other stimuli (see also Cravens & Renner, 1970). Nevertheless, the literature on ‘conditioned drive states’ shows that it may be possible to acquire CEOs in this way.

For example, a study by Calvin, Bicknell and Sperling (1953) suggests that it may be possible to establish a surrogate CEO for food in rats. They placed rats in a distinctively striped box for 30 min a day over a period of

[3] Though see Jansen (1994) for an account of binge eating in terms of conditioned anticipatory physiological responses.

[4] See Michael (1993) for discussion of the way in which surrogate CEOs can be distinguished from conditioned elicitors.

24 days. The first group of rats were placed in the box after 22 h of food deprivation and the second group were placed in the box after just 1 h of food deprivation. Following the 24-day training period both groups of rats were allowed free access to food in the striped box after 11.5 h of food deprivation. The rats with a history of being in the box after a 22 h deprivation period ate significantly more than those with a history of being in the box after a 1 h deprivation period. Thus by being reliably paired with food deprivation, the striped box may have come to function as a surrogate CEO for food amongst the first group of rats.

Subsequent attempts to replicate these results were, however, largely unsuccessful and a number of methodological problems make the findings difficult to interpret (Cravens & Renner, 1970). Weingarten (1985) has since argued that it is the case that stimuli can acquire food related motivative functions, but in order for them to do so, they must be associated with food or feeding as well as deprivation. In support of this claim he referred to a number of studies that showed that stimuli could be conditioned to bring about meal initiation in satiated animals or to increase intake of food relative to animals in a control condition. These effects were achieved by presenting a stimulus to food-deprived animals immediately prior to the presentation of food. Thus the stimulus was paired, not only with food deprivation, but also with food availability. Given that the stimulus elicited either feeding in the absence of food deprivation or resulted in a greater intake of food, it appears to have been functioning as a surrogate CEO for food. However, it is likely that it was also functioning as an SD for food.

Thus, at present, our knowledge of surrogate CEOs for food and water is very limited and further research is needed to determine the precise conditions under which they may occur. Bearing in mind these shortcomings in our understanding, it is nevertheless useful to consider the ways in which they might impact upon human eating behaviours. Indeed, a recent study by Durlach et al. (2002) suggests that such influence is possible. During a series of training sessions they asked participants to repeatedly consume two novel flavoured drinks; one whilst thirsty (i.e. after consuming a high salt meal) and the other whilst less thirsty (i.e. after consuming a low salt meal). When participants were subsequently given free access to the drinks during a testing session, they consumed almost twice as much as the one that had followed the high salt meal. Thus by being repeatedly paired with the high salt meal, the novel drink may have become a surrogate CEO for fluid consumption. This account seems especially likely given that, during the training sessions, participants were still thirsty after consuming the experimental drinks (more so for the one following the high salt meal), meaning that the drinks were reliably paired with thirst throughout the study.

It is also possible to conceive of a number of other situations in which surrogate CEOs for food and water might arise. In particular, it may be the case that certain stimuli tend to be encountered when food deprived. This may occur as a result of an individual seeking food, such as visiting a takeaway restaurant, or simply because these stimuli happen to be encountered at times of the day when one is most likely to be hungry, such as prior to lunch or on the journey home from work. These stimuli may take on motivative functions that, when encountered in the absence of food deprivation, still come to evoke behaviours associated with food consumption. For example, if an individual frequently visits a takeaway hamburger restaurant when hungry, the restaurant environment, because it has been reliably paired with food deprivation, may become a surrogate CEO for food. If the individual subsequently visits the restaurant when not food deprived, for example to purchase a drink or accompany a friend, the environment may bring about feelings of hunger and may result in the individual purchasing and eating a hamburger.[5]

Similarly, if individuals are consistently hungry it may be that a large number of environmental cues become paired with food deprivation and thus become surrogate CEOs for food, both increasing the reinforcing value of food and increasing the individual's response to cues associated with food. In addition, if particular foods tend to be eaten when hungry, and tend not to be eaten to satiation, it is possible that they themselves could also become surrogate CEOs for food. Support for the latter comes from the study described above by Durlach et al. (2002), in which drinks that were repeatedly paired with thirst, appeared to become surrogate CEOs for fluid consumption. Thus diets in which individuals are frequently hungry and/or rarely eat foods to satiation, may actually increase the likelihood of overeating, in part because a large number of environmental cues may be paired with hunger and in part because foods themselves may be paired with hunger.[6] Indeed, such an account would be consistent with research showing that in an experimental setting, restrained eaters tend to overeat in response to food cues (i.e. environmental cues) and to appetisers (i.e. the foods themselves) (Fedoroff et al., 1997, 2003; Jansen, 1994; Jansen & Van den Hout, 1991; Rogers & Hill, 1989).

Another area in which surrogate CEOs might occur is in relation to caffeine deprivation amongst physically dependent caffeine users. In this case, stimuli that become reliably paired with caffeine deprivation may eventually come to evoke caffeine consumption. Again, such stimuli could become paired with caffeine consumption because they tend to be encountered when the individual is seeking caffeine,

[5] One would, however, need to rule out the possibility that such behaviour occurred simply because the individual had no experience of consuming hamburgers in a non-deprived state (Dickinson & Balleine, 1994; Michael, 1993). This could be achieved, either by ensuring that they did have such experience or by determining whether hamburger purchasing in the non-deprived state occurred on more than one occasion.

[6] However, if overeating occurred too frequently, it seems likely that the CEOs would eventually be extinguished.

such as boiling the kettle or visiting the coffee shop, or simply because they happen to be encountered at times of the day when one tends to be caffeine deprived, such as first thing in the morning.

*Reflexive conditioned establishing operations*

Reflexive CEOs are previously neutral, environmental stimuli that acquire motivative functions by being correlated with some form of worsening or improvement. (The term ‘reflexive’ is used in the grammatical sense to indicate the effect of this CEO in altering its own function.) Where correlated with worsening, they establish their own termination as a reinforcer and evoke behaviours associated with their termination. Where correlated with improvement, they establish their own termination as a punisher and suppress behaviours associated with their termination. For example, if a rat learns that a particular tone is always followed by an electric shock, it will also learn to perform behaviours that terminate the tone. In this case the tone, as well as being a conditioned aversive event, is also a reflexive CEO that establishes its own termination as a reinforcer. Conversely, if a rat learns that a particular tone is always followed by food, it will also learn to suppress behaviours associated with the termination of the tone. Here the tone, as well as being a conditioned reinforcer, is also a reflexive CEO that establishes its own termination as a punisher.

Reflexive CEOs are relevant to a range of human eating and drinking behaviours. For example, amongst regular coffee drinkers, caffeine deprivation may cause aversive physiological responses such as headaches, fatigue and drowsiness (Silverman, Evans, Strain, & Griffiths, 1992; Van Dusseldorp & Katan, 1990). Coffee consumption will be negatively reinforced by the relief of such symptoms. However, if coffee drinkers pre-empt these symptoms by drinking coffee before they occur, symptom relief cannot therefore be used to account for their behaviour. On the other hand, stimuli that reliably precede these symptoms, such as a slight increase in thirst, or the length of time elapsed since the last coffee, may become both conditioned aversives and reflexive CEOs. They will establish their own termination as a reinforcer and evoke behaviours, such as drinking coffee, that are associated with their termination.[7]

Reflexive CEOs are also relevant to health related behaviours. For example, someone on a diet may have frequent thoughts of ‘forbidden’ foods such as chocolate and cake, or about restraining their eating. These thoughts may be intrusive and may disrupt the individual from tasks they are trying to concentrate on (e.g. see Boon, Stroebe, Schut, & Jansen, 1998; Green & Rogers, 1998). As a result, they are likely to be highly aversive. The presence of a forbidden food in the individual’s immediate environment, for example in the home, may be reliably correlated with an increase in the frequency and persistence of these thoughts and will therefore become a reflexive CEO, evoking behaviours associated with the removal of the food such as giving it away or eating it all in one go.

*Transitive conditioned motivating operations*

Transitive CMOs are environmental stimuli that acquire their motivative effects by being correlated with the correlation between another stimulus (S) and some form of improvement or worsening. (The term ‘transitive’ is again used in the grammatical sense, as with a transitive verb that takes a direct object.) As a result of this association, transitive CMOs come to alter the reinforcing or punishing effectiveness of S and to evoke or abate behaviours that have previously lead to S. For example, a man is about to make a cake. He is gathering together all the ingredients listed in the recipe when he discovers he does not have any sugar. He therefore walks to the local shop in order to buy sugar. Here, the word *sugar* on the list of ingredients is functioning as a transitive CEO for sugar.[8] This is because in the past, when sugar has been specified in a cake recipe, using sugar has been reliably correlated with cake (an unconditioned reinforcer). As a consequence, the term *sugar* in the recipe increases the reinforcing effectiveness of having sugar available and evokes behaviours (such as looking in the cupboard or going to the local shop) that have previously led to sugar.[9]

Again, the motivative functions of transitive CEOs are relevant to a range of eating behaviours. For example, a child may be told that if he eats his entire broccoli he can have pudding. In the past, this statement may have been associated with a correlation between an absence of broccoli on his plate and the provision of pudding. The statement therefore establishes a broccoli-free plate as a reinforcer and evokes behaviours, such as eating the broccoli, or feeding it

[7] Research shows that coffee drinkers can acquire flavour preferences for drinks containing caffeine, showing a preference for such drinks when caffeine deprived (Yeomans, Jackson, Lee, Nesic et al., 2000; Yeomans, Jackson, Lee, Steer et al., 2000; Yeomans, Spetch & Rogers, 1998). Thus it may be possible to account for ‘pre-emptive’ coffee drinking with reference to the reinforcing value of the flavour of the coffee, provided coffee becomes preferred prior to the onset of symptoms. However, it seems likely that reflexive CEOs and conditioned aversives also play a role. Indeed, it is possible that flavour preferences arise due to their association, not just with symptom relief, but also with the termination of conditioned aversives, as described above.

[8] In this example the word *sugar* on the list of ingredients cannot be viewed as an SD since its presence is not reliably paired with an increase in the *availability* of sugar. For example, even in the absence of the word, sugar will still have been available to buy at the local shop.

[9] It is possible that the man has never previously bought sugar at the local shop or successfully made a cake. From past experience with other foods he may also be aware that baking the cake without sugar will not taste the way it should. Thus his actions may be governed by *verbal behaviour* rather than by direct experience of the consequences of these activities (e.g. see Barnes-Holmes et al., 2001). Nevertheless, the recipe still functions as a transitive CEO for sugar. See Michael (1993) for a non-human (i.e. non-verbal) illustration of transitive CEOs.

to the dog, that have previously lead to a broccoli-free plate.[10]

Transitive CEOs can also help account for behaviour that occurs as a result of food or drink being available for a limited period only. For example, in England licensing laws mean that many bars and public houses stop serving alcohol at 11pm, with ‘last orders’ called at the bar a few minutes beforehand. In this case, the call for last orders may function as a transitive CEO that establishes a half empty glass as a punisher, since previously, when last orders has been called, a half empty glass is likely to have been correlated with having nothing to drink a little later on. Thus the call for last orders evokes behaviours that avoid having a half empty glass, such as buying another drink. A similar analysis can be applied to a number of situations in which food or drink is available for a limited period only. Indeed, the motivative effect of limiting the availability of an item is frequently employed to sell goods ranging from cars and holidays to alcoholic drinks and chocolate bars.

## Comparisons with other accounts of motivation

This section briefly describes three other accounts of motivation employed in the field of appetite research: incentive learning theory (Dickinson & Balleine, 1994), the conditioned modulatory stimulus model (Davidson, 1993) and two factor theory (Weingarten, 1985). These were selected since they are relatively contemporary accounts of feeding behaviour that are explicitly concerned with motivation. Importantly, all three make some attempt to consider instances of non-regulatory feeding (i.e. feeding in the absence of energy depletion). After briefly reviewing these theories, the section goes on to highlight the main ways in which they differ from the MO approach. These relate to (1) the ways in which they account for non-regulatory feeding, (2) the extent to which they address cognitive variables and (3) their underlying philosophical assumptions and subsequent relation to intervention.

[10] It has been argued that rewarding an individual for engaging in a particular task undermines his or her ‘intrinsic motivation’ for that task (e.g. see Deci et al., 1999). Indeed, some studies have reported that when access to a reward (e.g. pudding) is made contingent upon the consumption of a particular food (e.g. broccoli), children’s preference for that food (i.e. the broccoli) decreases (Birch et al., 1982; Birch et al., 1984; Newman & Taylor, 1992; see Lowe et al., 2004 for further discussion of this literature). A full account of this effect requires reference to theories of language and cognition as well as MOs (e.g. see Hayes, Barnes-Holmes and Roche, 2001b), a discussion of which is beyond the scope of the present article. Put simply however, the ‘if-then’ type relation (e.g. *if* you eat all your broccoli, *then* you can have pudding), functions as an abolishing operation for broccoli, the effects of which occur over a relatively long duration. The if-then relation acquires these motivative functions via its association with items the child does not enjoy eating (since children tend only to be rewarded in this way for eating foods they do not like).

### *Other accounts of motivation*

#### *Incentive learning theory*

Dickinson and Balleine (1994) state that goal-directed, instrumental actions are controlled by two motivational processes: (1) a Pavlovian motivational process, and (2) an incentive learning process. In the first, a Pavlovian association between an SD and an outcome (e.g. a sign for a restaurant and the availability of food), results in the SD acquiring motivational functions. These motivational functions are dependent upon the relevance of the outcome to the animal’s current motivational state (e.g. state of hunger) and will operate in the absence of prior experience of the outcome in the relevant motivational state. The second, incentive learning process, operates via the animal’s knowledge of the response-outcome relation. Here the motivational state has two distinct functions. Firstly, it determines the animal’s reaction to the outcome at the time of contact, which in turn determines the value the animal assigns to the outcome (e.g. in a state of hunger the animal will derive pleasure from food and thus assign a high value to it). The value an animal has assigned to an outcome then determines its instrumental responses. However, this assigned value is not automatically controlled by the motivational state. In other words, the assigned value will remain the same regardless of shifts in motivational state (e.g. an animal who has assigned a high value to food, will, under extinction, work just as hard to obtain food even when its motivational state has shifted from hunger to satiation). Hence the motivational state also has a second function in incentive learning; it comes to *control* the outcome value. That is, the animal learns to assign different values to the outcome depending on its current motivational state (e.g. a high value to food when hungry and a low value when satiated). This control of the outcome value is acquired only via direct experience of the outcome in the relevant motivational states (e.g. experience of food in states of both hunger and satiation).

Thus whilst both incentive learning theory and the MO account rely on Pavlovian associations between the reward and the SD, incentive learning theory also refers to a second process termed ‘incentive learning’. Although it is difficult to conclusively demonstrate that this second process is not also simply a result of Pavlovian associations (e.g., see Adams & Dickinson, 1981; Colwill & Rescorla, 1985), recent research now suggests that this is unlikely and that this second incentive process is mediated by a response-reinforcer relation rather than by Pavlovian associations (Corbit & Balleine, 2003; Dickinson, Campos, Varga, & Balleine, 1996). Data from neurobiological studies also support this claim (Dickinson, Smith, & Mirenowicz, 2000). In order to be able to account for these recent data, the MO concept would therefore need some further development.

Dickinson and Balleine (1994) do not explicitly discuss non-regulatory feeding. However, it is possible to speculate on the ways in which it may be accounted for. First, since the association between motivational state and outcome value is acquired through experience, if an individual only has experience of eating a particular food when hungry, he or she may not be sensitive to shifts in levels of food deprivation and thus may still eat the food when satiated (the so-called 'resistance to satiation' effect, see p. 7–8 of Dickinson & Balleine, 1994). However, in practice this is likely to account for only a small amount of non-regulatory feeding since presumably such an effect would disappear once food had been eaten in the satiated state. In addition, more recent research (Dickinson et al., 1995; Gibson & Desmond, 1999) suggests that when an animal/individual has extensive experience with a food they in fact become *more* sensitive to shifts in motivational state, being increasingly influenced by the Pavlovian SD-outcome process rather than the response-outcome process (see above). An alternative explanation is that assignment of outcome value is influenced by cognitive processes. Indeed, Dickinson and Balleine (1994) allude to this when they state "It is a feature of our own goal-directed behaviour that it can be deployed in the pursuit of abstract goals—honor, beauty, truth, and prestige, for example, the value of which must surely be socially conditioned and learned" (p.16). However, the way in which social conditioning might influence outcome values (and subsequently help account for non-regulatory feeding) is not explored. As Dickinson and Balleine (1994) note in their discussion of the determination of outcome value, "At present, we know next to nothing about the psychological processes underlying incentive learning".

*Conditioned modulatory stimulus model*

Davidson's (1993) conditioned modulatory stimulus model draws on elements of Booth's earlier model of compound stimuli (1985; Gibson & Booth, 1989). Like Booth, Davidson's account combines postingestive consequences with internal physiological cues and external food cues. However, whilst Booth emphasised food selection and preference, Davidson is more concerned with the general initiation of feeding, both regulatory and non-regulatory. For this reason his model was deemed more appropriate for comparison with the MO account.

Davidson (1993) proposes that food deprivation produces salient, internal physiological cues which exert behavioural control by functioning as conditioned modulatory stimuli. In other words, they control the strength of an association between a conditioned stimulus (CS) and an unconditioned stimulus (US). For example, the presence of physiological cues associated with food deprivation signal that cues arising from food (taste, smell, texture and visual features) or related to food will be followed by positive postingestive consequences. In contrast, when food deprivation cues are presented in isolation, or when food cues are presented in isolation, neither will be followed by positive postingestive consequences. Davidson suggests that the modulator (in this case food deprivation cues) works by decreasing the threshold for activation of the US memory (in this case the positive postingestive consequences) making it easier for the US memory to be evoked by the CS (in this case food cues). This in turn increases the extent to which the CS (food cues) elicit instrumental responding (e.g. feeding behaviour).

According to Davidson (1993), this model can also account for non-regulatory feeding via the occurrence of second-order CSs. Davidson refers to a study by Holland and Rescorla (1975) in which food deprived rats were taught to associate a light ($CS_1$) with food (US) and were then also taught to associate a tone ($CS_2$) with the light, i.e., they established both first-order conditioning ($CS_1$-US) and second-order conditioning ($CS_2$–$CS_1$). They then examined the effects of satiation on first and second order conditioned responses (CRs), operationalised as gross body movements that occurred during the CS presentation. The results showed that following satiation, first order CRs (i.e. responses to the light) were substantially reduced whereas second-order CRs (responses to the tone) remained unaffected. Davidson suggests that satiation disrupts first-order conditioned responding by removing the modulatory deprivation stimuli. However, since the $CS_2$ has little or no associative connection with the US representation, removing the modulatory stimuli has no impact on the conditioned responses to the $CS_2$. Davidson suggests that the occurrence of second-order CRs could therefore contribute to non-regulatory feeding since they will occur in the absence of hunger cues.

Davidson (1993) provides a very thorough account of the way in which hunger cues may bring about feeding. However, his discussion of non-regulatory feeding is brief and the precise details unspecified. As such, the exact manner by which second-order conditioning might bring about non-regulatory feeding is unclear and the account suffers from a number of shortcomings. First, the study by Holland and Rescorla (1975) examined the impact of the CSs on general activity. It did not examine food consumption or instrumental responding to obtain food. To the author's knowledge there have been no equivalent studies that have examined the effects of second-order conditioning on actual feeding behaviours. Second, Davidson states that activation of the US memory (via input from both the $CS_1$ and the modulator) makes it easier for the $CS_1$ to elicit feeding. This suggests some kind of feedback mechanism from the US memory to the $CS_1$ that makes the $CS_1$ more or less likely to elicit feeding. However, it is unclear how the $CS_2$ would elicit feeding. For example, it may do so via activation of a memory of the $CS_1$, (which has no association with the US memory), but it is unclear how activation of this memory would elicit food seeking behaviours or how it would interact with actual food cues. And third, in his discussion of regulatory feeding, Davidson refers to the US as the postingestive consequences of food and to the CS as 'the set of exteroceptive cues arising from the taste, texture and visual features of food or cues related to food' (Davidson, 1993, p. 649). This contrasts with his discussion of non-regulatory feeding in which he refers to the US as the presentation of food (which presumably precedes or co-occurs with the taste, texture and visual features of food) and the $CS_1$ as a tone signalling the presentation of food. Thus there is some ambiguity over exactly which cues function as USs. This is important since, according to Davidson, modulatory stimuli (such as cues associated with food deprivation) have a direct influence on the threshold at which the US memory is activated, but have no such direct influence on the CS.

*Two-factor theory*

Two factor theory, as described by Weingarten (1985) accounts for food intake via two mechanisms: one involving physiological cues associated with food deprivation (depletion-induced hunger) and the other founded on learning processes that lead to associations between external stimuli and food (incentive-induced hunger). According to Weingarten, depletion-induced hunger tends to be slow in onset, and increases the probability of the animal ingesting any food it encounters. In contrast, incentive-induced hunger is activated by exposure to cues associated with food and tends to be rapid in onset and specific to a particular type of food or manner of feeding. However, as Weingarten notes, the account does not specify the signals that control depletion-induced hunger, the ways in which conditioned cues operate to affect feeding or how depletion-induced hunger interacts with incentive-induced hunger.

*Comparisons with the MO account*

*Non-regulatory feeding*

A unique feature of the MO approach is the way in which it accounts for non-regulatory feeding. In contrast to the theories described above, the MO account predicts that environmental variables will take on motivative functions as a result of being paired with another MO (or 'motivational state'). This enables it to account for a wide range of situations in which individuals may eat or drink in the absence of deprivation cues.

For example, as described previously, if an individual associates a particular environment, for example a takeaway hamburger restaurant, with food deprivation cues, the environment itself may eventually come to elicit eating, even in the absence of food deprivation. Such a prediction is not readily derivable from either incentive learning theory or the conditioned modulatory stimulus model. According to incentive learning theory, eating would only be elicited if the individual had no experience of eating hamburgers in the absence hunger. As a result, this type of non-regulatory eating would not be sustained beyond its first occurrence since the individual would subsequently have experience of eating hamburgers in the non-deprived state. It is unclear how else incentive learning theory might account for such behaviour.

It is also unclear how the conditioned modulatory stimulus model would account for such behaviour. As outlined above, Davidson (1993) suggests that second order conditioning is responsible. Thus we might represent the postingestive consequences of the hamburger as the US, the taste, sight and smell of the hamburger as the $CS_1$, and the restaurant environment as the $CS_2$. According to Davidson, because the restaurant environment has no direct association with the postingestive consequences of the hamburger, it may elicit feeding in the absence of hunger. However, as described previously, the way in which it would elicit feeding is unclear. It may be that it activates a representation of the taste, sight and smell of a hamburger (i.e., a representation of the $CS_1$). However, one is still left with the problem of establishing the way in which this representation elicits feeding, or indeed interacts with the representation of the US.

In contrast, two factor theory can account for such feeding via reference to an association between the restaurant environment (an external stimulus) and food. Unlike two factor theory however, the MO account would predict that this type of feeding would also be elicited in response to environments, or other stimuli, that had been consistently paired with food deprivation but not with food consumption.

Similarly, as described previously, the MO account would also predict that individuals who are frequently hungry will be more likely to overeat in response to food cues, due to environmental cues (and possibly also foods themselves) becoming paired with deprivation; a prediction that is consistent with studies showing that even when restrained and unrestrained eaters are experiencing similar levels of food deprivation and/or reported hunger, restrained eaters will tend to eat more in response to food cues (Fedoroff et al., 1997, 2003; Jansen, 1994; Jansen & Van den Hout, 1991; Rogers & Hill, 1989). Again, incentive learning theory and the conditioned modulatory stimulus model do not readily lead to such predictions.

Thus compared to other theories of motivation, the MO approach provides more comprehensive coverage of non-regulatory feeding. It makes unique predictions, can account for existing findings and provides a sound theoretical framework to guide further empirical research. In addition, the MO approach incorporates cognitive variables, another important influence on non-regulatory feeding. This is discussed below.

*Cognitive variables*

For the purpose of comparison with other approaches, this section examines cognitive influences on feeding. However, it is important to note that the MO approach does not draw a distinction between 'cognitive' and 'non-cognitive' variables; all variables are accounted for by the same processes. This is arguably one of the strengths of the account since it provides both parsimony and scope; the same principles are employed to account for behaviour ranging from food deprivation and dehydration to health promotion and advertising.

Whilst other theories of motivation do not tend to address cognitive variables, for the MO account they do not represent a problem. For example, as illustrated previously, the MO approach uses the concept of transitive CEOs to account for the motivating effects of announcing 'last orders' at a bar (via the correlation of this type of announcement and a half empty drink with an absence of drink a little later on). This example is problematic for other theories of motivation. Two factor theory cannot account for this behaviour since drink will have been available for some length of time and the call for last orders signals the imminent *non-availability* of drink. Thus we need to be able to account for the sudden change in the reinforcing value of drink in the presence of the call for last orders. It is possible incentive learning theory could account for such an effect with reference to a change in the incentive value of drink. However, at present it is unclear exactly how this might come about.

The ways in which MOs account for cognitive variables certainly requires further empirical support. In many instances a full account is also likely to require reference to other theories of language and cognition (e.g. Hayes et al., 2001b). However, despite these shortcomings the MO approach nevertheless appears to be one step further towards an account of cognitive influences on feeding compared to other theories.

*Relationship to intervention*

The MO account also differs from the above theories in relation to its underlying philosophical assumptions. This in turn has implications for its relationship to intervention. The theories described above are process theories. In contrast, the MO account stems from the behaviour analytic tradition and employs a contextual or relational framework. As such, it differs from process theories in terms of its scientific objectives, units of analysis, views of causation, and requirements for explanation (Dougher, 1995; Hayes & Brownstein, 1986). For example, the aims of a process theory are description and prediction. Thus researchers strive to model the mechanisms that mediate the behavioural features observed in a given environment and test theories using predictive verification and falsification (Hayes, Barnes-Holmes, & Roche, 2001a, p143). For example, incentive-learning theory postulates underlying mechanisms (e.g. the encoding of action-outcome relations, see Balleine & Dickinson, 1998) in order to model and predict behaviour in different motivational states. To the extent that it is able to model and predict behaviour, it achieves its objectives.

Behaviour analytic theories employ a contextual framework and their goals are more pragmatic. Instead of attempting to model and predict, they aim to predict and influence. This has a number of implications for the way in which behaviour analytic theories are constructed.[11] First, they are not concerned with modelling underlying mechanisms. This does not mean that the modelling of underlying mechanisms contradicts behaviour analytic theories, merely that they do not help achieve their goals of prediction and influence. Second, since behaviour analytic theories are concerned with influence, the independent variables must be directly manipulable. Thus whilst incentive-learning theory might account for behaviour in terms of action-outcome representations, such an explanation would not be considered adequate in behaviour analytic theory since the independent variable (an action-outcome representation) cannot be manipulated directly. Behaviour analysts would instead seek to identify the environmental variables that influenced behaviour. This is precisely what the MO account does. It does not confirm or deny the presence of action–outcome representations, it simply does not consider them necessary to achieve prediction and influence. Instead, the focus of the analysis is on environmental variables that can be manipulated directly.

This difference can be illustrated using the concept of motivation itself. In appetite research the term 'motivation' has largely been used to refer to physiological or cognitive states (e.g. Waters et al., 2001), or to unspecified internal states that drive goal-directed behaviour (e.g. de Wit, 1996; McSweeney & Swindell, 1999). Thus motivation is viewed as something inside the individual that can only be manipulated indirectly. Whilst such a conceptualisation may help model and predict, it is less useful when ones aim is behavioural change since one still needs to specify the environmental variables that in turn influence motivation. This contrasts with the conceptualisation employed in MO theory. In this case MOs *are* environmental variables and thus are themselves the target for any intervention work.

Similarly, some theories may focus on physiological cues associated with food deprivation, i.e. feelings of hunger. These are not incompatible with the MO account. On the contrary, utilising knowledge of covert mechanisms is likely to be beneficial (e.g. see Donahoe et al., 1997). However, for the majority of applied research in the appetite field (e.g. healthy eating, obesity, eating disorders, consumer behaviour), we will ultimately be interested in altering variables other than hunger, for example consumption of specific foods. Whilst it would be possible to conceptualise hunger as an independent variable, in order to influence food consumption we would still need to go one step further and identify those variables that influenced hunger. We would also need to identify the contexts in which those variables influenced hunger and the contexts in which they did not. Even once we had managed to do this, we would probably find that hunger was not a perfect

[11] The emphasis on influence stems not just from a concern with the development of interventions, but is also necessary for the successful operation of contextualism. See Hayes and Brownstein (1986) for a full discussion of this issue.

predictor of food consumption so we would then need to identify the situations in which it did predict food consumption and the situations in which it did not, and so on. Whilst there is nothing inherently wrong with this approach, in practice, because the goals of process theories are to model and predict rather than to influence, they tend to concentrate on research that can either verify or falsify the theory. For example, there may be a series of experimental manipulations designed to determine the extent to which an animal can discriminate and respond to internal hunger cues (e.g. see Davidson, 1993). Whilst this information may be important for testing and developing the theory it is arguably less critical for the development of interventions.

In contrast to this approach, in behaviour analysis the behaviour of interest cannot be defined or understood without reference to the context in which it occurs. As such a behaviour analytic approach to appetite research moves the focus of analysis away from hunger (and other covert mechanisms) and towards the environmental variables that can be shown to reliably influence the behaviours of interest (e.g. consumption of a specific food). Such variables may include food deprivation (i.e. an absence of food consumption for a sustained period) but may also include other variables shown to influence food consumption (e.g. observation of others eating a specific food, see Horne et al., 2004; Lowe et al., 2004; Tapper et al., 2003). In all instances the behaviour of interest is defined in relation to the situational and historical context in which it occurs. Thus the research is used to inform us about the nature of particular events within a specific domain rather than the nature of a particular theory. In this way it is more directly applicable to the development of interventions.

The contents pages of appetite and nutrition related journals reveal that a substantial amount of research relates to applied areas such as healthy eating, obesity, eating disorders and consumer behaviour. It is reasonable to assume that much of this research is prompted by a desire, not just to model and predict, but also to influence. Whilst it is true that process theories can lead to effective interventions, they are nevertheless still founded on a scientific paradigm that takes modelling and prediction as its primary goal (Dougher, 1995). As such, they will not always specify environmental variables that can be manipulated directly in intervention work. Although relevant environmental variables may eventually be specified, in a behaviour-analytic approach they will be integral from the very start. Thus where we hope to intervene, it is likely that a behaviour analytic approach will point more immediately towards potential interventions strategies.

## Concluding remarks

The aim of this article is to introduce readers to the concept of MOs and to highlight the ways in which this could contribute to the field of appetite research. Although the MO concept requires some further development to enable it to account for recent data (see above) the strengths of the MO approach can be seen to lie in its utility for intervention work and in its applicability to both regulatory and non-regulatory feeding, and to both cognitive and non-cognitive influences. However, since MO theory represents just one of a number of important theoretical advances in behaviour analysis, the article is not intended as a complete account of eating behaviour. In particular, the complex cognitive processes that arguably play a very significant role in much human eating behaviour means that any comprehensive account would need to draw heavily on theories of language and cognition as well as MOs (e.g. see Hayes, Barnes-Holmes, & Roche, 2001b).

It is also important to note that the examples provided are for illustrative purposes and, in many cases, there is an absence of empirical support for the involvement of MOs in the manner described. Thus further research is needed to determine the extent to which MOs, particularly CMOs, contribute to human eating behaviours. Such research may ultimately show that CMOs are not easily acquired in eating related behaviours or that they apply to a very limited range of situations that perhaps tend not to generalise beyond the laboratory. However, this is an empirical matter, and given their potential significance, such research seems worth pursuing.

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