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Value-based choice: An integrative, neuroscience-informed model of health goals

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Objective: Traditional models of health behaviour focus on the roles of cognitive, personality and social-cognitive constructs (e.g. executive function, grit, self-efficacy), and give less attention to the process by which these constructs interact in the moment that a health-relevant choice is made. Health psychology needs a process-focused account of how various factors are integrated to produce the decisions that determine health behaviour.
Design: I present an integrative value-based choice model of health behaviour, which characterises the mechanism by which a variety of factors come together to determine behaviour. This model imports knowledge from research on behavioural economics and neuroscience about how choices are made to the study of health behaviour, and uses that knowledge to generate novel predictions about how to change health behaviour. I describe anomalies in value-based choice that can be exploited for health promotion, and review neuroimaging evidence about the involvement of midline dopamine structures in tracking and integrating value-related information during choice. I highlight how this knowledge can bring insights to health psychology using illustrative case of healthy eating.
Conclusion: Value-based choice is a viable model for health behaviour and opens new avenues for mechanism-focused intervention.

Keywords: motivation; health goals; value-based choice; behavioural economics; translational neuroscience

Introduction and background

Psychology research has traditionally focused on personality and cognitive factors as key determinants of health behaviour. For example, the personality trait conscientiousness has been linked with a large number of health behaviours and their downstream consequences (Bogg & Roberts, 2004; Turiano, Chapman, Gruenewald, & Mroczek, 2015), and classic theories of health behaviour change focus on cognitive processes such as planning, intentions, beliefs and higher order cognition (Armitage & Conner, 2001; Hofmann, Friese, & Strack, 2009; Webb & Sheeran, 2007). Evidence has clearly shown all of these factors to be important in understanding and changing health behaviour. Nonetheless, personality and cognition are each, on their own, only part of the story. What is lacking is a more mechanistic, process-based account of how various

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factors are *integrated* in the moment that health-relevant decisions are made. A successful account of this type would describe how various features of the person (e.g. conscientiousness, self-efficacy beliefs) and the situation (e.g. social pressure, habit cues) come together during choice, and also generate new avenues for intervention that follow from the more detailed description of the choice process.

In this paper, I articulate a framework for viewing health behaviour and health behaviour change as the outcome of a value-based choice process. This framework focuses on a common problem: one where a person possesses the necessary skills, information and resources to engage in a given health behaviour, and yet chooses not to. This is the case, for example, in healthy eating when an individual has resources and access to fruits and vegetables. When structural barriers to obtaining healthy foods are removed, why do people still choose unhealthy ones? Value-based choice is a general model for understanding many types of everyday decisions, including health-related decisions. In value-based choice, choice options are identified, each salient attribute of the options is assigned a *subjective value*, and a decision is made through a dynamic integration process. In addressing the problem described above, the value-based choice model emphasises the relative salience of the options, the value of their various attributes to the chooser and the choice process itself.

In the next section, I describe how health behaviour can be characterised as a result of a value-based choice process, and how this characterisation fits with existing models of health behaviour. I then turn to the implications of that model for understanding health behaviour, using healthy eating as an illustrative example. Finally, I present a research agenda that follows from important outstanding questions for the model.

Health behaviour as value-based choice

Assuming a set of basic cognitive skills and knowledge, many health behaviours can be modelled as a simple choice (or a series of choices) among a set of options. Choice behaviour – including health-related choice – has been studied extensively within psychology, often in the decision-making literature, and the allied field of behavioural economics (Rangel, Camerer, & Montague, 2008). The basic model adopted in these fields is that choice is driven by a comparison of the *subjective value* (or utility) of the options presented, and, as assumed here, it is given that people have the information and cognitive skills necessary to enact any one option in a set of choices. An advantage of modelling health behaviour in this way is that the knowledge gained from other fields about value-based choice, such as its predictable anomalies and neurobiological underpinnings, can be imported into health psychology and used to generate novel insights into how health-related decisions are made and how to alter them.

By way of definition, I use the term valuation to refer to a unified process wherein multiple, heterogeneous sources of value and cost (i.e. input processes) for each option in a choice are translated into a common metric and integrated to allow a comparison between options; the most valued option is then enacted (see Figure 1). For example, in the classic dieter's dilemma, the value of a healthy choice might be a function of the feeling of progress towards a long-term goal (+), social signalling of commitment to health (+), and the monetary and effort costs (–) of obtaining it; the value of an unhealthy choice might be a function of the hedonic liking of the food (+), the relative ease of acquisition (+) and the social cost of acting against one's stated goal (–).

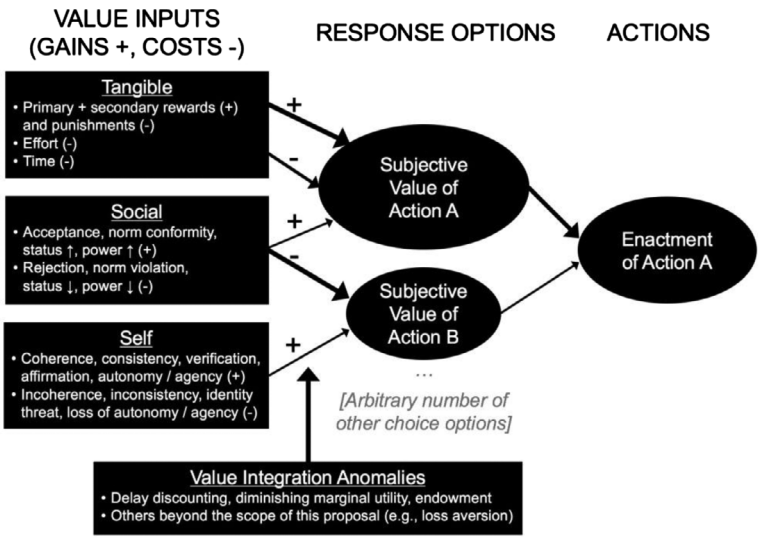

Figure 1. Value-based choice.
Notes: Options are evaluated through a value accumulation process, and the option with the greatest subjective value at the time of choice is enacted. Sources of value can be divided into tangible (e.g. food), social (e.g. approval), and self-related (e.g. consistency) categories, where '+' indicates positive value or gains and '–' indicates negative value or costs.

Which choice is enacted is determined by the relative combined weight of the value sources for each option. A simple valuation process provides a surprisingly robust model of decisions related to self-control, and can account for patterns of choice as well as their phenomenology and associated neural activation (Berkman, Hutcherson, Livingston, Kahn, & Inzlicht, in press).

In this model, choice is driven proximally by three main factors: the options present in the choice set, the sources of value (and cost) that contribute to each and predictable features of the valuation process itself, such as that it tends to discount the value of temporally distant rewards. In turn, personality and cognitive factors might contribute by influencing the choice set or moderating the valuation processes, as described further below. When faced with a choice among options that one is capable of enacting, the options that are salient in the moment – for whatever reason – and their subjective values ultimately determine choice. What is typically called self-regulation 'success', such as choosing to eat a healthy food, merely reflects the outcome of a decision-making processes whereby an option consistent with a health goal was enacted; 'failure' reflects the outcome *of the same process* whereby a competing, unhealthy action was enacted. Improving health behaviour, therefore, entails finding ways to increase the value of behaviours related to the health goal, decrease the value of unhealthy or goal-counter behaviours and/or alter the choice set so it contains more healthy and fewer unhealthy options.

A value-based choice process is a good candidate model of health behaviours because it presents a mechanistic account of how a broad range of processes, including personality and cognitive ones, as well as others, contribute to health behaviour and

suggests novel pathways for intervention based on properties of the integration process. A decision-based view of self-regulation is aligned with models of choice in neuroscience and behavioural economics, so the substantial existing knowledge base and theoretical principles from those disciplines can be ported into the study of health behaviours. For instance, I explain below that value-based choice is subject to the 'delay discounting' phenomenon observed in behavioural economics, whereby the subjective value of a delayed reward is less than an (objectively) equivalent immediate reward. From this perspective, so-called self-regulation failures related to immediate choice such as overindulgence in dieting can be explained by properties of the valuation system: just as the value of future rewards is discounted, the value of health goals may be discounted if they are viewed as achieved only in the future. Finally, neuroeconomics has consistently implicated a network of midline dopamine regions in the calculation of subjective value, notably the ventromedial prefrontal cortex (vmPFC) and the ventral striatum (vS). As reviewed below, these regions appear to track subjective value across a variety of stimulus domains, receive inputs from a range of cortical and subcortical structures and predict choice behaviour. These brain regions are candidate neural mechanisms of valuation and potential targets of interventions on health behaviour.

Intersection with traditional models of health behaviour

Value-based choice represents a framework for integrating concepts from models of health behaviour that would otherwise remain siloed. The model espoused here complements and connects many standard theories of health behaviour and health behaviour change because it describes the process of how a choice is made in the moment. Table 1 illustrates how a variety of constructs that have been linked to health behaviour can feed in to and modulate a value-based choice process, including constructs related to personality, attitudes and beliefs, and executive function. I selected these three because

Table 1. Examples of how various constructs could influence value-based choice.

	Locus of construct's effects in the value-based choice process		
Construct type	Choice Set	Attributes and Weights	Valuation Process
Personality	*Conscientiousness*: Include expert guidance (e.g. doctor's advice) in the choice set when C is high	*Extraversion*: Increase weight of social attributes such as approval when E is high	*Grit*: Smaller effect of delay discounting on long-term goals when grit is high
Attitude / Belief	*Personal relevance*: Healthy options excluded from choice set when health risk is not seen as personally relevant	*Perceived risk*: Prevention behaviours weighted more strongly when perceived risk is high	*Self-efficacy*: Reduce probability discounting of healthy options when they are seen as more likely to be attained
Executive Function	*Working memory*: More options included in choice set when working memory is high	*Attention*: More thorough survey of choice attributes when attentional focus is broad	*Fluid intelligence*: Faster accumulation of value for abstract attributes when processing speed is high

they represent a range of perspectives and are popular in the research literature. I do not mean to suggest that they are the only ones that contribute to value-based choice; on the contrary, these examples are meant to be illustrative of health behaviour theories can be viewed through the lens of value-based choice.

For example, the personality trait of conscientiousness has been linked to a range of health behaviours including tobacco use, diet, physical activity and drug and alcohol use (Bogg & Roberts, 2004). But the pathways that (presumably) cause a highly conscientiousness person to be more likely to engage in a given health behaviour are unknown. The value-based choice model of health behaviours presents testable mechanistic hypotheses at several points in the model. It is possible, for instance, that highly conscientious people are more likely to include behaviours that are recommended by their doctors in the choice set when selecting a course of action. Conscientiousness might also bias attention towards small but important health-relevant attributes (e.g. the presence or absence of artificial preservatives in food products), which might otherwise go unnoticed and thus not contribute to the valuation process.

Attitudes and beliefs can also exert influence at multiple locations in the value-based choice process. For example, self-efficacy has long been known to be a key factor in determining health behaviour and response to behaviour change interventions, presumably by increasing the perceived feasibility of behaviour change (Holden, 1992). The mechanisms by which self-efficacy operates in the moment of choice are relatively understudied; value-based choice presents a way of doing so. By increasing the perceived likelihood of a behaviour, self-efficacy might mitigate *probability discounting*, or the tendency to reduce the subjective value of improbable rewards (Green & Myerson, 2004). Similarly, executive functions such as working memory, attentional control and fluid intelligence might expand the maximum size of the choice set, influence the depth with which attributes are processed and increase the speed of value accumulation, respectively, any of which could have substantial effects on health behaviour (e.g. Hutcherson, Bushong, & Rangel, 2015; Sullivan, Hutcherson, Harris, & Rangel, 2015).

These examples also illustrate two key advantages of viewing health behaviour as an instance of value-based choice. The first is that the model accommodates multiple input processes to a choice, so several constructs can influence behaviour at once. In this way, value-based choice can integrate ideas from several models, such as by testing the possibility that extraversion and perceived risk and working memory might each have an effect on a given health decision. The second advantage is that the model suggests specific avenues for intervention. The model adds to what is already known about behaviour change (e.g. increasing self-efficacy, decreasing perceived barriers) and uncovers several other options for intervention based on properties of the valuation process itself. In the following sections, I discuss these properties and describe how they can be leveraged to develop and refine health behaviour interventions.

Insights into health behaviour from value-based choice

Research in behavioural economics has identified an assortment of anomalies in value-based choice. In general, the anomalous behaviour involves cases where people's behaviour does not maximise gains or is inconsistent across time even though the gains and losses do not change (e.g. Kahneman, Knetsch, & Thaler, 1991; Loewenstein & Thaler, 1989). These anomalies are of interest to economists because they violate

economic models such as expected utility theory (von Neumann & Morgenstern, 1953), which holds that people's decisions maximise expected utility and are not influenced by 'supposedly irrelevant factors' such as when in time the gain will occur (Thaler, 2015). The field of behavioural economics emerged to study these anomalies using empirical means and to update economic models based on predictable, if suboptimal, empirical patterns of behaviour during economic choice (Camerer & Loewenstein, 2004).

Since the inception of the field in the 1970s, researchers in behavioural economics developed tools to evoke these behavioural anomalies in the lab and, thereby, generated a body of work that illustrates when these anomalies occur and describes them with formal models. This work assumes that economic choice is driven by a subjective value (or utility) calculation, and has shown that the anomalies can be explained by regularities in the way that objective gains and losses are translated into subjective value. Three of these anomalies in economic choice are particularly relevant to health behaviour, though economists have discovered many others.

Endowment

The endowment effect refers to the asymmetry of the value people place on the same object when they sell it vs. when they buy it: people ask a higher price as owners than they are willing to pay as buyers (Thaler, 1980). For example, while Richard might be willing to pay no more than $50 for a nice bottle of wine, he might require over $100 to part with the same bottle from his beloved collection (Thaler, 2015). Even studies that control for the obvious reasons for the asymmetry, such as the seller's loss aversion, still reveal an endowment effect (Morewedge, Shu, Gilbert, & Wilson, 2009), indicating that humans place an inherent value on mere ownership: it appears that ownership of a thing or trait simply confers value to it.

In terms of its relevance to health goals, the endowment effect suggests that goals or traits that are seen as part of the self will have higher value than those that are not, and are thus more likely to be enacted when they conflict with other actions or behaviours. This prediction has not yet been tested directly, but there is a variety of research that supports it indirectly (mostly following Self-Determination Theory; Deci & Ryan, 1985). For example, goals that are chosen freely, that reflect the true self, are easier to implement and regulate, as evident by behaviour and brain (Legault & Inzlicht, 2013); such goals are also less likely to be countered by competing goals or obstacles (Milyavskaya, Inzlicht, Hope, & Koestner, 2015).

Temporal discounting

One of the most perplexing violations of utility maximisation is that humans tend to 'discount' gains as a function of time such that the equivalent amount of money is apparently worth less to us in the future than it is in the present (Ainslie, 1975; Green & Myerson, 2004). This anomaly is most apparent when people make choices between options that vary in both time and nominal value, known as 'intertemporal choices'. It is anomalous, for example, that most people would choose to gain $101 in 13 months instead of $100 in 12 months, yet also choose $100 now instead of $101 one month from now. Neoclassical gain-maximisation models incorrectly predict that people should choose the larger amount regardless of the delay because both choices involve a gain of $1 over one month.

The implication for health behaviours is that the subjective value of psychologically distal options – those that are less likely, physically further away and more abstract – will be less than the subjective value of psychologically proximal options, even when the choice's objective value is held constant. Manipulations that counteract that asymmetry by reducing the mental distance to the distal option, or by increasing the psychological distance to the proximal option, are predicted to facilitate health behaviours. Perhaps the most vivid example of this is the classic marshmallow studies, in which children generally had difficulty waiting for two unseen marshmallows in favour of a single visible one. However, children who directed their attention away from the physically present marshmallow were better able to wait for the other two (e.g. Mischel & Ebbesen, 1970). More recently, Fujita and colleagues have shown that construing a goal in abstract, high-level terms (e.g. thinking about *why* you want to be healthy) increases self-regulation related to that goal, presumably because drawing attention to the goal increases its salience and reduces the psychological distance to it (Fujita, Trope, Liberman, & Levin-Sagi, 2006). For example, high-level (versus low-level) construal reduces snacking on unhealthy foods (Price, Higgs, & Lee, 2016), perhaps because it connects long-term, abstract goals such as health with specific, in-the-moment behaviours, thereby making the abstract goal more concrete and tangible. The value-based choice model predicts that any manipulation that alters psychological distance in these ways should produce similar effects.

Another implication for health goals is that behaviour in real world, repeated choices will vary systematically when the choice options consistently differ in time delay. This is the case, for example, in weight loss, where individuals repeatedly encounter tempting foods, and where the gain derived from tasty but high-calorie foods is immediate and certain, but the gain derived from losing weight is delayed and uncertain. Even if the two (qualitatively different) gains were objectively equivalent, the subjective value of the delayed gain is discounted because it is psychologically distant, providing an economic lens to understand why weight loss is such a difficult behaviour to achieve.

Diminishing marginal utility

Diminishing marginal utility refers to the phenomenon that each additional unit of gain leads to an ever-smaller increase in subjective value (Figure 2). For example, three bites of candy are better than two bites, but the twentieth bite doesn't add much to the experience beyond the nineteenth (and often makes it worse). This effect is so well established that it is referred to as the 'law' of diminishing marginal utility in economics (Gossen, 1854/1983), and is reflected in the concave shape of subjective utility functions (e.g. Kahneman & Tversky, 1979; Rabin, 2000). A consequence is that subjective value changes dynamically near the zero point but levels off as gains (or costs) accumulate.

The tendency for returns on subjective value to diminish with repetition is relevant to how health goals play out over time. Health-relevant decisions often appear as a choice between a behaviour that promotes a high-level or distal goal (e.g. health) and a competing behaviour that satisfies a low-level or proximal goal or impulse (e.g. indulgence). Both options have some degree of subjective value, even if that value is derived from a different source (such as the sense of accomplishment that accompanies goal

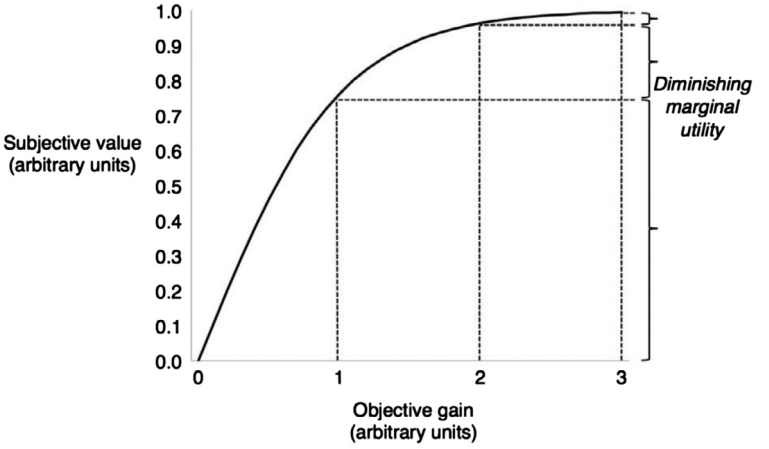

Figure 2. Diminishing marginal utility of gains.
Notes: Given a concave relationship between objective gains (*x*-axis) and subjective value (*y*-axis), each one-unit gain produces a smaller increase in subjective value than the previous gain of an equal unit. The marginal utility, or the change in subjective value above the existing level, diminishes as gains increase (shown on the *y*-axis to the right).

completion compared to the immediate physical gratification associated with a positive experience). Therefore, recent positive experiences that diminish the subjective value of one but not the other goal will alter self-regulation.

Health disparities

There is now irrefutable evidence of disparities in health behaviour as a function of socio-economic status (SES; Adler & Newman, 2002) and race and ethnicity (Singer, 2012), among other demographic variables. Much of the research on these disparities has examined the important roles that factors such as access to resources, chronic stress and policy play in creating and perpetuating those disparities. Additionally, SES and race/ethnicity might influence health behaviour through direct or indirect effects on the value-based choice process. Poverty itself or its associated stressors and stigma, for example, could systematically bias the kinds of choice options that are considered, the relative weights of their attributes or the way anomalies influence choice. I consider two such examples in this section.

Behavioural economists have begun to uncover the profound impacts that poverty, specifically, and resource scarcity, more generally, have no choice. Having limited resources in terms of money, time or even turns in a video games causes a particular kind of myopia: out of necessity, scarcity forces people to focus more deeply on the problem at hand, often to the exclusion of considering the future (Shah, Mullainathan, & Shafir, 2012). For example, when video game players were assigned to be ‘poor’ (3 shots per level) or ‘rich’ (15 shots per level), and could borrow additional shots against their point totals, poor players shot more accurately but borrowed considerably more, to the point that they ultimately earned less per shot than rich players (Shah et al., 2012). This result mirrors the observation that low SES people tend to borrow

more money, and at higher rates, than they can afford, and suggests the mechanism of this apparently self-destructive behaviour is not ignorance but rather necessity. In a similar way, low SES might influence health behaviours by restricting the choice set and strongly biasing choices towards immediate needs rather than longer term considerations (Berkman, 2015).

Cultural factors that are linked with race and ethnicity can also systematically influence the choice process. For example, *familism* is a value that emphasises family and prioritising the needs of the family, and it is prominent in Hispanic cultures. People high in familism are more likely to consider the effect of their choices on their family members – a choice attribute that might not even occur to people low in familism. Depending on the behaviour in question, familism could influence health for the better or worse. For example, familism among Latino/a youth can be a protective factor against drug use because of its negative effects on family members (Telzer, Gonzales, & Fuligni, 2014), but familism could also be an impediment to dietary change because of the important role meal rituals play in family cohesion (Fiese et al., 2002). Nonetheless, familism illustrates how cultural values and practices could influence value-based choice in ways that might contribute to racial and ethnic disparities in health behaviour.

Neuroscience

Much of the knowledge about how value-based choice works comes from the neuroeconomics literature. There, theories explicitly conceptualise decision-making as unified value function that compares the values of the possible responses, where the response with the highest subjective value is chosen (Rangel et al., 2008). Studies adopting this approach consistently find that activation in several regions within the mesolimbic dopamine system, notably including the vmPFC, the vS and the orbitofrontal cortex (OFC) is involved in value computations of both appetitive and aversive stimuli (Tom, Fox, Trepel, & Poldrack, 2007). This system has many functions related to reward learning and reward prediction. Broadly, it tracks reward contingencies to optimise future behaviour (Berridge, 2006). One of its key functions appears to be the integration of information across a range of properties about a stimulus to produce a unified value signal that integrates stimulus properties, active goals, costs and other types of choice-relevant information such as those mentioned above (Rangel, 2011). As such, the function of the vmPFC, vS and OFC during choice fits well within the broader literature on motivation and reward, particularly the role of these regions in tracking and reflecting the motivational component of 'wanting', as opposed to 'liking' rewards (Berridge & Robinson, 2003).

To provide a sense of the specificity of this network's activation to reward valuation, I conducted a reverse inference meta-analysis using the Neurosynth tool (Yarkoni, Poldrack, Nichols, Van Essen, & Wager, 2011). This procedure used all 11,406 studies currently in the Neurosynth database to answer the question: among all studies that report activation in these regions, how likely are the terms 'value' or 'valuation' to appear? In other words, how likely are these regions to be involved in valuation relative to other processes? As shown in Figure 3, studies that report activation in vmPFC, vS and OFC are highly likely to discuss value, suggesting a fair degree of specificity of the valuation process to these regions.

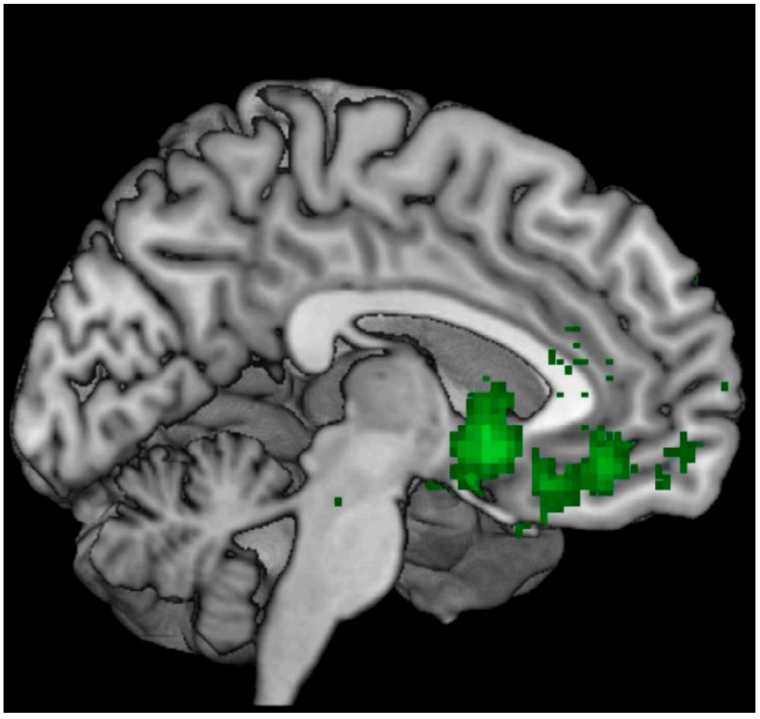

Figure 3. A reverse inference meta-analysis of the term 'value' based on the Neurosynth tool (Yarkoni et al., 2011).
Notes: Results are based on 11,406 total studies in the database, 344 of which use the term 'value.' The reverse inference procedure estimate the probability of the term 'value' given activation in a region. As depicted, vmPFC, vS, and OFC are selective for valuation in the sense that the term 'value' is relatively likely to appear in the text of studies that report activation in those regions compared to other terms in the database.

In one illustrative study (Hare, Camerer, & Rangel, 2009) participants separately rated the tastiness and healthiness of a series of food stimuli, and then made choices about whether or not to eat each food (with one choice randomly selected at the conclusion of the study and actually given to the participant to eat). Activity in vmPFC predicted stimulus value and choice regardless of whether that choice was driven by health or taste concerns. Interestingly, lateral prefrontal regions often implicated in self-control were functionally coupled with the vmPFC during healthy choice, suggesting these regions might promote self-control by increasing the value of 'controlled' options such as healthy choices, rather than by inhibiting the value of temptations per se. (See Kable & Glimcher, 2007; for a similar pattern of results.) In another study (Hare, Camerer, Knoepfle, O'Doherty, & Rangel, 2010), activity in vmPFC at the time of choice correlated with previous ratings of the subjective value of charitable organisations. As in the previous study, the vmPFC received inputs from lateral cortical regions – this time those associated with social cognition that were active when placing value on charitable gifts. In both these studies, the vmPFC appears to be a point of integration of value

information from diverse sources (e.g. taste and health concerns) during decisions related to health behaviour.

In further support of the notion of vmPFC as the locus of a unified value integration process, the vmPFC appears to translate the value of various types of stimuli into a common value unit. For instance, vmPFC activity predicts choices regardless of whether the stimuli in question are food or money (Levy & Glimcher, 2011), and vmPFC activity scales with the subjective value of a monetary gain for oneself and another person (Zaki, López, & Mitchell, 2014). In the latter study, participants first chose between gains for themselves and gains for another person. Based on these responses, a scaling factor was computed to describe the relative value of gains for oneself and another (e.g. if I'm equally likely to keep $8 for myself as I am to give $4 to you, then my scaling factor between self and other is 2). Then, in a separate set of trials, gains were offered separately to the self or the other. In these trials, vmPFC activity linearly scaled with the *subjective* value of the gains (e.g. was equal for an $8 gain for you and a $4 gain for myself). Not only does vmPFC reflect value, then, but it also scales value across disparate outcome types in a unified valuation system to facilitate choice among them (Levy & Glimcher, 2011), making this region a plausible candidate to be a locus of value inputs from a variety of qualitatively different input processes.

The established knowledge from behavioural economics and neuroscience about value-based choice can inform a new wave of research on health behaviour. In a subsequent section, I will apply the lessons learned from these fields to the example topic of healthy eating. But it is first important to consider the input processes that contribute value and costs to choice options.

A case study of value-based choice for health psychology: healthy eating

Healthy eating has been the running example throughout this paper, but in each case the value-based choice model was used to explain, *post hoc*, some known phenomenon of healthy eating (e.g. weight loss is hard because the gains associated with a distal outcome are discounted). Here, I illustrate the usefulness of the value-based choice model in generating new hypotheses about ways to intervene on eating. The following are examples of testable predictions that would not be apparent in other models of health behaviour that do not account for various anomalies in the process of valuation.

The endowment effect suggests that choice options that are owned or otherwise seen as part of the self or extended self will have higher value than options that are not. Ownership here need not be literal, and extends to symbolic ownership or authorship. Social psychologists have developed a veritable toolkit of ways to manipulate perceptions of ownership that could be applied within health behaviour. For instance, cognitive dissonance (or self-perception) could be leveraged to convince people that they value a goal; working towards a goal with insufficient external justification is likely to cause people to believe that they must value the goal (Festinger, 1957). A way to test this would be to invoke dissonance using a classic ease-of-retrieval manipulation where participants retrieve from memory few vs. many (e.g. six vs. 12) instances when they acted on a healthy eating (Schwarz et al., 1991). It is generally easier to recall six than 12 instances of anything, so participants in the six-instance condition interpret the ease-of-retrieval as a signal that they are committed to the goal of healthy eating and would be expected to feel greater ownership of it than participants in the 12-instance

condition. Generally, any manipulation that increases the degree to which a goal is seen as self-relevant will endow that goal with value, thereby making healthy options related to the health goal more likely to be enacted.

The basic prediction from delay discounting is that proximal choices will have higher value than distal ones, particularly in terms of time but also in other forms of psychological distance. This anomaly poses a particular challenge for health goals because temptations usually arise in the present moment and are thus undiscounted, whereas long-term health goals are by definition psychologically distant and therefore their value is discounted. A prediction is that bringing goals into the present moment or making them more psychological proximal will change the relative value of the two options. Goals can be made more psychologically proximal by making them tangible and bringing them into the present moment. For example, providing people who wish to change their eating patterns with a physical object that reminds them of their goal is expected based on this principle to increase the value of the healthy eating goal. Conversely, pushing both options into the psychological future would reduce the discrepancy between them because the value of each (and not just the distal goal) would be discounted. An intervention where sated people (e.g. who just ate) made choices for future meals is expected to produce more healthful decisions than in-the-moment choices. These example studies follow directly from hyperbolic time discounting.

The law of diminishing marginal utility suggests a handy way to reduce the subjective value of short-term temptations: consumption. If a hedonic pleasure has recently been experienced, then the subsequent value of other similar pleasures will be reduced. By extension, it is possible that even *imagining* consuming a temptation would diminish the marginal utility of the temptation. Consistent with this prediction, imagining eating an unhealthy food (M&Ms) 30 times reduces actual eating (Morewedge, Huh, & Vosgerau, 2010), whereas imagining eating that same food only a few times increases eating (consistent with the elaborated intrusion theory of desire; Kavanagh, Andrade, & May, 2005). In theory, the diminishing marginal utility extends to any form of short-term temptation that runs counter to a goal. This prediction would be somewhat counterintuitive outside of the value-based choice model – generally people are advised to avoid the siren song of their favoured temptation lest they get pulled in – but evidence about diminishing marginal utility indicates that the more often and more vividly someone imagines the experience of consuming a temptation, the *less* value that temptation will hold for that person in the moments that follow. The Morewedge et al. (2010) study suggest the intriguing possibility that the utility derived from *eating* a food is at least in part interchangeable with the utility derived from *visualizing* eating the food. If so, then diminishing marginal utility using visualisation would be a promising avenue for health behaviour change interventions.

Finally, the neuroimaging evidence presented above implicates the vmPFC as a mechanism of valuation during health-related choices. This means that the vmPFC should not only mediate the effects of any value-based intervention on food choice, but also that its pattern of neural activity should track with subjective value (and its anomalies) during food choice. For instance, in the example above on diminishing marginal utility through visualisation, the value-based choice model predicts that vmPFC activity in response to previously imagined tasty foods would be reduced compared to vmPFC activity in response to never-imagined tasty foods. The relative activity in this region is expected to be predictive of food choice (e.g. Hare et al., 2009), and brain regions

associated with salient properties of a choice option (e.g. its healthiness) are expected to show increased functional connectivity with the vmPFC during choice (e.g. Hutcherson, Plassmann, Gross, & Rangel, 2012). A consistent neuroanatomical system for self-regulation has remained elusive (Kelley, Wagner, & Heatherton, 2015), in part because existing models tend to confound successful self-regulation such as healthy choices with executive function activity, and failed self-regulation such as unhealthy choices with impulsivity or reward system activity. As noted above, executive function is not the only path to healthy decisions. The value-based choice model of health behaviour implicates a specific neural region in both healthy and unhealthy choice, the vmPFC, and indicates that the key difference between the two is found in the relative connectivity of input processes to the vmPFC. Thus, an advantage of a valuation account is that it makes testable predictions about the patterns of function and connectivity that are expected to mediate the effects of value-based interventions on health behaviours such as food choice.

Impediments to progress to be addressed by future research

The value-based choice model of health behaviour raises many questions, some of which remain unanswered. In prioritising which questions to tackle first, I am reminded of the forefather of social psychology, Kurt Lewin, who reportedly challenged psychologists in saying that 'if you truly want to understand something, try to change it'. Lewin's quote suggests that an intervention can be a strong test of a theory. And health psychology faces a dearth of advice for people seeking help with changing health behaviours. Not all theories of self-control are readily adaptable to intervention tests (e.g. trait-focused models of health behaviour), and others have seen strong predictions of change through intervention fail (e.g. improving healthy choices through cognitive control or self-control training programmes). The value-based choice model lends itself to prescriptive tests well because it specifies a mechanistic process (valuation) with a well-characterised neuroanatomical system (vmPFC and related regions) for a behavioural phenotype (health-related decisions) that relate to a broad range of socially costly outcomes. And studies have already shown that the valuation process can be modelled computationally and neurally (e.g. Rangel & Hare, 2010). The next step is to develop intervention studies that target valuation at the psychological and, ideally, neural levels (Fisher & Berkman, 2015). I suggest that answering the following three questions is a particularly important step for the field to make substantial progress in the near future.

Is it possible to know all the sources of value in a choice?

The flexibility of the number and nature of the input processes to valuation is both a strength and weakness of the model. It is a strength because it allows for differences in the causes of motivation for a given action both across people and within a person across time. A person might choose to eat broccoli because of social pressure on one day, a price discount on another and the particular salience of health concerns on yet another. Also, the flexibility in inputs may simply be a realistic representation of how health behaviour occurs in naturalistically. But this flexibility presents a challenge to scientists who seek to explain or predict behaviour a priori. To make the problem more

tractable, health psychologists will need a way to analyse the relevant input processes to a choice given a person and a situation. I offered above an initial outline of what this may include (i.e. tangible, social, and self-related value sources) but this list needs to be tested and validated, and extended beyond the person to account for situational variation as well. For example, the 'DIAMONDS' taxonomy of situations (Rauthmann et al., 2014) could be a fruitful starting point for efforts to identify the various value sources at play in various contexts.

What is the link between the moment-to-moment process of valuation and traits related to successful goal pursuit?

Trait-focused explanations of health behaviour can be seen as complementary to process-focused accounts and not necessarily competitive with them. The value-based choice model does not address the question of how choices accumulate to contribute to a profile of a 'healthy person', just as the link between conscientiousness and health behaviours does not explain the process by which that trait (presumably) causes those behaviours. There must be some connection – people who are healthy tend to find a way to make healthy choices – but the exact nature of that connection is unknown. In identifying the reasons why certain traits bias behaviour towards healthy choices, researchers will also uncover new leverage points for behaviour change.

One can imagine a number of explanations. Perhaps healthy people tend to create choice sets with a greater number of healthy and fewer unhealthy options. Perhaps healthy people have similar choice sets to unhealthy people but weigh the value of healthy choices more through reduced temporal discounting. Perhaps they have similar discounting curves but devalue unhealthy choices somehow. Efforts are underway to bridge the gap between momentary choice and long-term outcomes, particularly in the domain of self-control. For example, the process model of self-control (Duckworth, Gendler, & Gross, 2014, 2016) highlights that there are many ways people can align their choices with their goals, from avoiding situations where goal-counter choices are likely, to modifying situations, to directing attention to alternative choices. This work and research along similar lines, which maps out the variety of paths that lead people to arrive at healthy and unhealthy choices, will explain how and why particular individual differences contribute to health behaviour, and will ultimately suggest new intervention strategies.

What are some 'renewable' sources of value that can motivate health behaviour in an enduring way?

Research on behavioural economics and neuroeconomics has made substantial progress in establishing notable properties of the valuation process including its regular anomalies and neuroanatomical pathways. I noted above some ways that this knowledge can inform interventions, such as by taking advantage of temporal discounting to promote healthy choices. However, it is not known whether interventions can actually modify the value of health-related choice options in a sustainable way. For example, contingency management therapy, wherein the value of abstinence from using a drug is increased with monetary incentives, is a highly effective treatment for substance use disorders (Bigelow & Silverman, 1999), but only while the incentives are provided (Prendergast, Podus, Finney, Greenwell, & Roll, 2006). This fits with the prediction of

the value-based choice model: tangible gains will increase the likelihood of healthy choice, but the calculation will change in the absence of those gains. In this sense, tangible gains are not renewable.

There is indirect evidence that it is possible to intervene on value inputs themselves – essentially to change the subjective value assigned to a choice option – and that doing so alters health-related behaviour in the expected direction. A promising recent developing is recent work that seeks to alter valuation through implicit processes such as associative learning or even cognitive dissonance. For example, 'evaluative conditioning' has been shown to increase the value of healthy food (and decrease the value of unhealthy food) by pairing it with stimuli that already have positive (or negative) valence (Bui & Fazio, 2016; Lebens et al., 2011). Interventions that use principles from cognitive dissonance, such as publically committing to engage in a particular behaviour, can have long-lasting effects on a range of health behaviours, including healthy eating (Freijy & Kothe, 2013), presumably because dissonance leads to changes in the underlying value of a behaviour (Stice, Marti, Spoor, Presnell, & Shaw, 2008). Finally, identity-based interventions, such as helping people to foster a 'healthy eater' identity, also may promote long-term change because of the relatively stable nature of one's identity and self-concept (Berkman, Kahn, & Livingston, 2016).

Conclusion

I presented a model of health behaviour as a value-based choice process. This process accumulates subjective value 'evidence' for each perceived option in the vmPFC and enacts the option with the greatest overall value. In this model, failures of health behaviour (i.e. making an unhealthy choice) in cases when an individual is aware of and capable of making a healthy choice can be understood in terms of anomalies in the general system such as the endowment effect, temporal discounting and diminishing marginal utility. The extensive knowledge garnered about the valuation system from behavioural economics and neuroscience research can be leveraged to identify ways to motivate health behaviour. In general, a more computationally specific, neurally characterised and prescriptive way of modelling the motivational forces at work during health-related choice is a major advance for the field.

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