Neuroeconomics, Health Psychology, and the Interdisciplinary Study of Preventative Health Behavior

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Key words: neuroeconomics, health psychology, health behavior, prevention, prevention science, decision neuroscience, translational neuroscience
The goal of this article is to introduce readers to theories, tools, and evidence from the field of neuroeconomics and to describe how health psychology and neuroeconomics can be mutually informative in the study of preventative health behaviors. Preventative health behavior here refers to both individual actions that impact one’s health (e.g. exercise) and broader behavioral patterns, such as those captured in personality constructs. While neuroeconomic researchers have begun to incorporate health relevant behaviors into their studies, the full potential of this research to inform preventative health models is as yet unrealized. What is needed to “translate up” is the unification of rich theoretical content from health psychology with investigations by neuroeconomic researchers of the decision making process during health relevant choices. We identify choice as a central, shared feature across models of preventative health behavior that can serve as an inroad for neuroeconomics to contribute to existing models and highlight commonalities that might not otherwise be apparent. A central premise of our argument is that, because health decisions are nearly always multiply determined, a more precise and mechanistic understanding of how choices are made is an important but understudied topic in health psychology. A partnership between health psychologists and neuroeconomic researchers can yield valuable insights into how preventative health choice is made and to identify targets and methods for intervention.
Running head: NEUROECONOMICS OF PREVENTATIVE HEALTH BEHAVIOR

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A long held and central tenet of health psychology is that many contemporary diseases are preventable. A small set of health risking behaviors including smoking, unhealthy diet, and sedentary behavior confers risk for a large proportion of preventable diseases. The field of health psychology has burgeoned since these early observations by Matarazzo, (1980, 1982), but the insight that decision making is a common denominator in preventable disease remains acutely applicable today. Individual decisions about health behaviors constitute the single greatest health care cost in the United States and lead to roughly 40 percent of preventable deaths each year (Bickel et al., 2017; McGinnis, Williams-Russo, & Knickman, 2002; Schroeder, 2007). This article introduces readers to theories, tools, and evidence from the field of neuroeconomics (also referred to as “decision neuroscience”) and describes how health psychology and neuroeconomics can mutually inform the study of preventative health behavior.

A central premise of our argument is that, because health decisions are nearly always multiply determined, a more precise and mechanistic understanding of how choices are made is an important but understudied topic in health psychology. Throughout this paper, we use the term “health behaviors” to refer to both individual actions that impact one’s health and broader behavioral patterns, such as those captured in personality constructs (Gochman, 1982; Rogers, Prentice-Dunn, & Gochman, 1997). There are many structural and contextual preconditions that must be met before a person can even make a health-relevant choice. We restrict our focus to specific ways that neuroeconomics adds to the study of health behavior in circumstances in which a person has the opportunity and ability to make a choice about a simple health behavior (e.g., whether to get a flu shot).
A combined neuroeconomic and health psychology approach provides several unique advantages for the study of health-relevant choices: (1) coherence of the field around a set of biologically rooted constructs (e.g., subjective value) described in a common language across fields, (2) concept parameterization, which helps make theories more measurable, falsifiable, and parsimonious, and (3) confirmatory evidence for existing models (Clithero, Tankersley, & Huettel, 2008; Fehr & Rangel, 2011; Glimcher & Rustichini, 2004). The discussion in this paper is situated at the intersection of neuroeconomics and health psychology, with a focus on neuroeconomic tools, the decision making process, and why choice is a worthwhile focus in the study of health. Selected studies illustrate the strengths of a neuroeconomic approach to health choice and provide the basis for a discussion of how neuroeconomics and traditional health models can be combined to improve health outcomes by influencing preventative health behavior.

**Choice as a Unifying Process for Health Psychology and Neuroeconomics**

Preventative health behaviors are a key focus of health psychology, a field that is itself composed of numerous research areas with variegated focuses on the internal and external contexts that contribute to health outcomes. These areas of focus include biological and evolutionary contexts, cultural contexts, interpersonal or personality contexts, and intrapersonal or social contexts outcomes (Barth, Schneider, & von Känel, 2010; Carver & Connor-Smith, 2010; Holt-Lunstad, Smith, & Layton, 2010, MacLean, Blundell, Mennella, & Batterham, 2017; Uskul, Sherman, & Fitzgibbon, 2009). In these contexts, behavioral patterns emerge that in their aggregate contribute to better or worse health outcomes. One way to unite these different perspectives in the study of health is by zooming out and taking an ecological approach, which attempts to
generate models that provide comprehensive, multilevel principles for health interventions by integrating theory from each of the areas depicted in Figure 1. Ecological models, however, do not generally specify the variables and processes important for changes in health behavior and focus instead on how existing theories can be applied to physical, sociocultural, and organizational environments to guide the development and application of health interventions (Sallis & Owen, 2014). Health models in each context suggest factors that influence preventative health choices, but, critically, the mechanistic details of how those choices are made remain opaque (Umberson, Crosnoe, & Reczek, 2010).

A complementary approach is to zoom in, to focus on the process of choice itself as a way to unite health models from the many areas of health psychology. With its long history of research on choice under varying conditions, the field of neuroeconomics can contribute to existing health models and highlight commonalities that might not be otherwise apparent. Centering on choice unifies health models at the process level with an explicit focus on variables that influence health behavior, which provides an inroad for collaboration between the fields of health psychology and neuroeconomics.

**Benefits of a Neuroeconomic Approach**

The field of neuroeconomics sits at the interface of psychology, economics, and neuroscience and aims to understand the processes by which decision making operates (Clithero et al., 2008; Fehr & Rangel, 2011; Loewenstein, Rick, & Cohen, 2008). Neuroeconomics integrates the behavioral study of decision making with neuroimaging methods to produce biologically constrained models of individual choice (Camerer, 2013; Glimcher & Rustichini, 2004). Research in neuroeconomics has made some initial forays into the realm of health behavior,
generating research on drug addiction, nicotine dependence, and unhealthy eating (Monterosso, Piray, & Luo, 2012; Schmidt et al., 2018; Sharp, Monterosso, & Montague, 2012; Sheffer et al., 2013). However, there remains unrealized potential for reciprocal contributions between neuroeconomics, which is relatively new to health topics but has a rich corpus of research on choice, and health psychology, in which health is the primary focus but in which the processes involved in health outcomes can sometimes be a more peripheral focus than the health outcomes themselves. The two central topics around which these fields have organized themselves, choice and health behavior, are inherently complementary (see Figure 2). Active collaboration between the fields can generate a more refined scientific understanding of health behaviors in a way that can lead to preventive interventions.

The benefits of a neuroeconomic approach to the study of health behavior can be broadly broken down into three categories, which are unpacked further in the subsequent sections.

(1) Using neuroeconomic tools, both behavioral and technological, can provide a means to parameterize the concepts used in health models. This makes theories more measurable, falsifiable, and parsimonious.

(2) Understanding how choices happen can facilitate coherence around a set of biologically plausible constructs such as subjective value that can be described in a common language across fields.
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(3) Understanding *why* choices about health unfold as they do may help provide confirmatory or disconfirmatory evidence for existing models of health behavior.

**Neuroeconomic Tools**

Incentivized Elicitation of Value

Many neuroeconomic studies infer people’s decision values through “incentive compatible” tasks in which participants’ decisions during the task have real implications. One popular task often adapted for neuroeconomic studies is the Becker–DeGroot–Marschak procedure, which can directly elicit subjective value (BDM; Becker, DeGroot, & Marschak, 1964). Consider the following example. During a BDM task, participants are allotted a small endowment (e.g., $5.00) to purchase items. Participants then view a series of images depicting options, such as food items, and for each item select their maximum “reservation price” (i.e., their willingness to pay). After the task, a trial is selected at random and the stated willingness to pay (e.g., $2 for a bag of chips) is compared to a randomly generated value (e.g., drawing a random price between $0 and $5). If the stated willingness to pay exceeds that value, the participant receives (and is sometimes instructed to consume) the item, paying the randomly generated price from their endowment. If the bid does not win the item, the participant keeps all the money. Therefore, it is incentive compatible to bid exactly what one is willing to pay for an item. The BDM thus allows researchers to estimate participants’ willingness to pay for each item in the stimulus set, an outcome measure considered representative of subjects’ decision value for a given option. This task is often coupled with neuroimaging methods.

**Neuroimaging Methods**
Neuroeconomics leverages neuroimaging tools ranging from direct measures of brain activity at the cellular level such as single cell measurement through measures of aggregate activity of groups of neurons to lesion studies where brain function is inferred by observation of behavioral deficits. Measures of aggregate activity also vary on the time-scale of measurable activity, ranging from milliseconds (electroencephalography, event-related brain potentials, magnetoencephalography) to seconds-to-minutes (functional magnetic resonance imaging [fMRI], positron emission tomography) to hours or longer (transcranial magnetic stimulation, lesion studies). The key advantage of using neuroimaging to study choice is to provide a common minimal level of analysis that is shared across theories of decision making, rooting psychological phenomena in the biological processes from which they originate (Glimcher & Rustichini, 2004).

Neuroimaging as applied to health models can help identify how various constructs function within the architecture of the brain and provide (dis)confirmatory evidence for descriptive or mechanistic models. For example, many decision models revolve around difficult to measure constructs such as subjective value; neuroimaging can help identify whether or not these types of computations are biologically plausible within what is known about the physical limitations and observable processes of the human brain. Neuroimaging also has the potential to identify overlap in constructs that have been given different names but share substantial processes at the neural level (Shiv et al., 2005). In so doing, psychological and economic models of behavior can be adjusted to reflect the underlying mechanisms from which behaviors arise, making them more parsimonious and domain general.
One way that neuroimaging studies have proved useful is by identifying underlying biological mechanisms of health-related choices. One brain region in particular, the ventromedial prefrontal cortex, is implicated across studies of value-based decision making. This region appears to calculate an aggregate decision value signal that plays a role in choice (Bartra, McGuire, & Kable, 2013; Clithero & Rangel, 2014). A pair of studies by Chib and colleagues (Chib, Rangel, Shimojo, & O’Doherty, 2009) provided some of the first evidence that ventromedial prefrontal cortex encodes a common decision value across stimulus types. Decision values for three categories of goods (money, food, and non-food trinkets) were calculated for participants and modeled with decision outcomes against blood oxygen level dependent (BOLD) signal during an fMRI scan. In both studies, participants completed a pre-scan BDM task to capture their valuations. In the first study, the pre-scan phase was followed by an fMRI scan during which participants made a binary choice between their median bid from the BDM task and each good.

The second study (Chib et al., 2009) was identical but for one change: a food item equal in value of the median BDM bid served as the reference object in the binary choice task. Participants in the second study made choices only between food items, so the observed behavioral and neural data generalize beyond money alone. In both studies, BOLD signal in the ventromedial prefrontal cortex was positively correlated with subjects’ willingness to pay, suggesting a common decision value representation for both food and money. An absence of unique activation for willingness to pay specific to only food or money in the ventromedial prefrontal cortex or elsewhere in the brain suggests that the overall subjective value of a stimulus is encoded by the ventromedial prefrontal cortex, rather than stimulus specific attributes (e.g. dollar amount or taste).
Evidence for a common value representation in the ventromedial prefrontal cortex suggests an underlying process by which health promoting behavior may be increased without focusing directly on health relevant attributes. Indeed, incentivization, which leverages monetary incentives to bias decision value in favor of a desired outcome, has been used in the health field with promising results for addiction and weight loss and shows potential to improve treatment adherence, engagement with preventative health services, vaccination rates, and HIV testing rates (Higgins, Silverman, Sigmon, & Naito, 2012; Ranganathan & Lagarde, 2012). Clearly defining the decision process under investigation (decision value) in the terms of a behavioral economic framework, contributes to consilience of the health and decision sciences as advocated for by Glimcher and Rustichini (2004). While the studies by Chib et al. provide confirmatory evidence for the role of the ventromedial prefrontal cortex as a common final pathway for decision value, subsequent research presents a more detailed account of the how value is calculated and modulated at a neural level.

A series of fMRI studies by Hare and colleagues also support the role of the ventromedial prefrontal cortex in encoding a common value signal during choice and provide further insight into how value is modulated by other psychological and neural processes (Hare, Camerer, & Rangel, 2009; Hare, Malmaud, & Rangel, 2011; Hare, O’Doherty, Camerer, Schultz, & Rangel, 2008). In a study with dieters, Hare and colleagues (2009) identified the dorsolateral prefrontal cortex as modulating value in the ventromedial prefrontal cortex on successful self-control trials. On trials where participants made choices about liked-unhealthy foods, which pose a challenge for dieting participants, dorsolateral prefrontal cortex, along with another region (inferior frontal...
gyrus), modulated ventromedial prefrontal cortex activity in a way that suggested that health concerns were incorporated into the decision. In a second study, Hare and colleagues (2011) found that even among non-dieters, health cues increased preference for healthier foods whereas taste cues did not affect food choice, likely because people always pay attention to taste. This suggests that drawing attention to the healthiness of food options can lead to a preference for healthier options independent of an explicit goal to eat healthfully.

This study added additional confirmatory evidence for a model of value-based choice in which the ventromedial prefrontal cortex represents overall value of decision options. Furthermore, coupling of the dorsolateral prefrontal cortex and inferior frontal gyrus was involved in modulation of subjective value away from immediate reward and toward better long-term choices. While these findings help to flesh out a neural model of decision making and self-control, the spotlight on overall decision value and not on differences in the representation of specific stimulus attributes (e.g. taste) leaves open the question of how value is assigned to different attributes to arrive at the decision value.

**How Health Choices Happen**

As an introduction to modeling choice via a neuroeconomic framework, a few select models are highlighted, but there are many more worth investigating that are beyond the scope of this introductory paper.

**Multi-attribute Models of Decision Making**
One prominent set of neuroeconomic models can be grouped under the heading of multi-attribute theories of decision making. Multi-attribute models of decision making are a class of computational models that describe how the basic attributes of choice options come together to influence the decision process. The premise of these models is that consumers see choice options as comprised of many attributes (e.g., a cupcake has flavor, texture, calories, and so on). Importantly, consumers vary in how they weight attributes, thus implying different attributes will contribute more to the ultimate choice for different consumers (Fishburn, 1967; Luce & Tukey, 1964; McFadden, 1973).

Using vaccination against flu as an example, a decision maker considers potential rewards and punishments (e.g., protection against flu, pain of injection) that vary in their influence (weight) on the total subjective value of that choice. During a decision, the summed weights of each option are combined to produce an overall subjective value for vaccination. The total values of the various choice options are compared and the outcome with the greatest subjective value is enacted. For an individual who highly values their health, the total value of vaccination will be greater than for an individual who equally weights other attributes but who undervalues health (see Figure 3). This empirical strategy has a long and expansive history (e.g., Green, Krieger, & Wind, 2001). There is also growing evidence that a multi-attribute framework can be applied to neuroeconomic studies of subjective value in the brain (Clithero & Rangel, 2013).

**Bounded Accumulation Models**

In bounded accumulation models (often referred to as “sequential sampling models”), information relevant to the value of each option is sampled over time until it reaches a decision
threshold at which point the corresponding decision is enacted (see Busemeyer, Gluth, Rieskamp, & Turner, 2019 for a recent review). One popular class of bounded accumulation models, the Drift-Diffusion Model, was developed as a computational tool to model the cognitive processes underlying response time data in simple, binary-choice tasks (Ratcliff, 1978; Voss, Nagler, & Lerche, 2013). By parameterizing distinct cognitive processes (e.g., evidence accumulation, decision threshold), Drift-Diffusion Models provide clearly defined metrics for psychological processes relevant to choice. There are four parameters in the basic Drift-Diffusion Model (Ratcliff, 1978; Ratcliff & McKoon, 2008) the rate at which information is accumulated (drift rate), the distance between decision thresholds at which evidence is sufficient to make a choice for or against an option (threshold separation), the starting point relative to each decision threshold, and the time elapsed that is not used toward making a decision (non-decision time; Clithero & Rangel, 2013; Rangel & Hare, 2010). These parameters are used in value-based decision making to model a subjective value parameter, often referred to as ‘action value,’ that is computed by integrating stimulus value and action cost over time. The action value is an integrated representation of an option’s overall subjective value, composed of the associated action costs, which reflect an option’s unpleasantness or difficulty independent of potential benefits; and stimulus values, which reflect an option’s expected benefits independent of action costs. In Drift Diffusion Models, a relative action value is accumulated over time by a noisy comparator process until it exceeds the threshold for or against a choice option (see Figure 4).

Returning to our flu shot example, consider an individual who passes a sign reminding them to get their annual flu shot. This individual may have a history of effective vaccinations that biases them toward getting the shot that day, setting their starting point closer to the ‘Yes’ option and
contributing to a threshold separation that is large with less evidence accumulation required for a
‘Yes’ decision than a ‘No’. However, the individual may quickly contemplate the action costs of
fitting in the vaccination to their busy schedule, thus resulting in a ‘No’ decision option as that
outweighs the positive components of getting the shot (e.g., peace of mind, contributing to herd
immunity). However, the next day, when passing a vaccination clinic where a flu shot is offered
on the spot, the effort of getting vaccinated reduces to almost nothing, resulting in fewer action
costs and allowing the action value signal to accumulate quickly toward a ‘Yes’ response. The
individual then makes a quick decision in favor of vaccination. As this example demonstrates,
the multi-attribute framework for weighting choices is compatible with bounded accumulation
models.

A recent study by Tusche & Hutcherson, (2018) used a multi-attribute model as the overarching
framework within which to contextualize social and non-social choice and to identify and
compare choice attributes. They combined computational modeling and fMRI to more precisely
uncover how cognitive regulation changes value representations during choice: at the level of
specific attributes of the choice options or at a general level of value integration. Two value tasks
were used in the study, one with food stimuli and one with monetary rewards for the self or a
partner. Results from the Drift-Diffusion Model that estimated the weight afforded to attributes
(taste and health for food, self-focus, other-focus, and fairness in the monetary task), provided
evidence that goal-consistent choice was supported by increased weighting of goal-relevant
attributes and decreased weighting of goal-inconsistent attributes.
Consistent with the hypothesis that value is modulated at the specific attribute level and not at the general choice level, Tusche and Hutcherson were able to decode specific representations for some individual attributes in the dorsolateral prefrontal cortex (taste, health, self-focus), temporal parietal junction, and precuneus (other-focus). Even those attributes represented in the dorsolateral prefrontal cortex could be independently identified by their unique patterns of activation. Accordant with prior work, activity in the ventromedial prefrontal cortex correlated with overall decision values across social and non-social choice, but activation did not scale with variations in attribute weights. Consistent with the hypothesis that value is modulated at a domain general level, the dorsolateral prefrontal cortex did represent multiple attributes across domains and it is possible that the correlation in regulatory success across social and non-social conditions found in the study relate to the dorsolateral prefrontal cortex as the common denominator.

Neuroeconomic studies present an opportunity to directly test components of health models and to provide mechanistic explanations of the processes underlying preventative health behaviors. Given that social attributes (e.g., social norms) are represented by different brain regions than health aspects of a stimulus, individuals who show deficits in self-regulatory behavior and who don’t respond to interventions focusing on attributes like self-relevant health or food taste could benefit from a reorientation toward the impact of one’s health choices on others (Tusche & Hutcherson, 2018). Careful investigation of how specific attributes are represented at a neural level, and the identification of systematic differences across people in those representations, could provide insight into how various and sometimes competing goals can be combined to promote health behavior.
Neuroeconomics provides information about decision making under constraints: risk, uncertainty, time pressure, and so on. These existing models of choice have particular relevance for preventative health choices, in which the decision maker is often acting on imperfect information and making a choice about probabilistic outcomes with innumerable known and unknown risks.

Prospect Theory and the Health Belief Model

Prospect Theory (Kahneman & Tversky, 1979) was one of the first psychological theories to strongly influence economic models of decision making. A key prediction of Prospect Theory is that people will act differently based on whether a situation is framed as a gain or loss as compared to some reference point. Research on Prospect Theory has shown that losses are typically felt more strongly than gains of the same magnitude, that individuals are less likely to take risks when they are already doing well, and that as the magnitude of gains or losses increases, sensitivity to them diminishes (Kahneman & Tversky, 1979). Prospect Theory is particularly relevant for health decisions. Individuals differ in how they value health, often in reference to their current health, and any health relevant decision is inherently risky: their health could improve (gain) or worsen (loss; Treadwell & Lenert, 1999). The reference point may have particular impact for preventative health behaviors that are themselves unpleasant, as in the case of vaccinations or invasive cancer screenings for which the risk of the immediate negative outcome (e.g. pain) feels more certain and salient than the potential long term outcome if the
behavior is not enacted (e.g. illness severity; Schwartz, Goldberg, & Hazen, 2008; Witteman et al., 2015).

A second contribution of Prospect Theory is the decision weight function, which describes how probabilities are weighted during choice. The function over-values very low and very high probabilities and especially over-weights certainty (Tversky & Fox, 1995). Overweighting certainty is particularly relevant for choices about health behavior, which are often probabilistic. Prospect Theory predicts that reframing health outcomes with respect to certainty would change choices about health behaviors. For example, when the human papillomavirus vaccine is described as 100% effective against 70% of cervical cancers, people are more likely to express vaccination intentions than when the same vaccine is described as 70% effective against 100% of cervical cancers (Li & Chapman, 2009).

To demonstrate the usefulness of Prospect Theory in relation to health, it is useful to discuss the Health Belief Model (Hochbaum, 1958; Rosenstock, 1960), a prominent health psychology model that is at its core about preventative health choice. The Health Belief Model was developed as an attempt to explain why people sometimes do not choose to engage in preventive health behaviors, even when means to do so are provided. The model posits that key factors influencing health choices are at their core about perceptions: perceptions of one’s own susceptibility to a disease, the seriousness of the consequences, the potential for risk reduction, the benefits of action, and the barriers to action. Despite the Health Belief Model’s popularity, ambiguity about how Health Belief Model constructs should be defined, measured, and related to
one another has led to inconsistencies in how the model is applied to health (Sugg Skinner, Tiro, & Champion, 2014). This is where Prospect Theory can be of use.

One way to consistently define perceived susceptibility is as risk, a central component of Prospect theory. A meta-analysis of studies investigating the relationship between risk perception and vaccination rates found that carefully defining risk in relation to the individual and structuring definitions of risk around the Health Belief Model constructs of likelihood, susceptibility, and severity, provided stronger evidence of a clear relationship between risk and health behavior than did meta-analysis that did not clearly define risk (Brewer et al., 2007). Identifying Health Belief Model constructs as consistent with risk allows for direct translation between the Health Belief Model and Prospect Theory, a model of decision making with an extensive neuroeconomic and behavioral literature on the effects of risk perception (Breiter, Aharon, Kahneman, Dale, & Shizgal, 2001; Schwartz et al., 2008; Tom, Fox, Trepel, & Poldrack, 2007). A clearly defined and well parameterized model of health behavior can provide the basis for a common language to discuss and investigate preventative health behaviors.

Social Psychological Influences on Value-based Choice

A recent recasting of value-based choice models in social psychological terms emphasizes the breadth of psychological processes that can contribute to the valuation process (Berkman, 2018; Berkman, Livingston, & Kahn, 2017). In more than 100 years of research into human behavior, psychology has identified a wealth of theoretical constructs (e.g., social influence) that can be added to computational models of decision making to increase their ecological validity.
From a social psychological perspective, the process of value accumulation unfolds not in the same way every time but varies from choice to choice depending on the psychological context. Therefore, the value-based choice model proposed by Berkman and colleagues highlights situational influences on the value accumulation process such as the relative salience of the choice attributes and the social context. This social psychologically-informed model is primarily concerned with which attributes contribute to a choice in a given moment and can still be estimated using Drift-Diffusion Models or other bounded accumulation models.

A key insight of this framework is that choice can be altered to promote healthy choices by strategically intervening on sources of value or on the way the decisions are contextualized. In accordance with a common description of attributes (e.g., Rangel, 2013), valued attributes can take the form of basic, immediate outcomes (e.g. physical sensations, incentives) or of more abstract, long-term outcomes (e.g. health consequences, social rewards). For example, initially, an individual may decide against getting a flu shot. However, by offering a lollipop as an incentive or making pro-vaccine social expectations salient could shift weight to the pro-vaccination side and increase the likelihood of a decision in favor of vaccinating against the flu.

The theory also suggests that attributes can alternately weigh for or against an outcome depending on the context and that this flexibility is built into the decision process without necessitating the existence of additional systems (e.g., as in dual-process models). For example, peer influence could promote or prevent vaccination depending on the specific peers in question, which is simply reflected in varying weights assigned to peer influence on the decision values. The flexibility inherent to value-based choice models provides a framework to model how psychological theories affect choices.
A series of studies by Enax and colleagues directly tested whether increasing the salience of health relevant attributes could bias behavior toward healthier choices. Studies in which health information was provided in a simple, color-coded nutrition label increased the overall proportion of choices for healthy over unhealthy food (Enax, Hu, Trautner, & Weber, 2015; Enax, Krajbich, & Weber, 2016). Like in previous studies, activity in the ventromedial prefrontal cortex scaled with decision value as indicated by participants’ willingness to pay for a food item. Consistent with attribute-specific value modulation, choices about foods with unhealthy labels were associated with increased dorsolateral prefrontal cortex and left inferior frontal gyrus activation, and with greater functional connectivity of these regions to ventromedial prefrontal cortex. Choices about foods with healthy labels were not associated with dorsolateral prefrontal cortex activity.

A third study by Enax and colleagues (Enax, Krapp, Piehl, & Weber, 2015) presents a twist on the usual experimental paradigm because it contrasts social value (i.e., ethical production) with the value of health and taste attributes. Participants’ willingness to pay was greater for items with a fair-trade emblem than for the identical item without the emblem, presumably reflecting the value of ethical production. This difference was reflected by activity in the ventral striatum, anterior cingulate cortex, superior frontal gyrus, and posterior cingulate cortex. Notably, in contrast to the studies focusing on health and taste attributes, the dorsolateral prefrontal cortex was not implicated as a modulator of attribute value. These results, combined with the findings of Tusche & Hutcherson (2018), suggest there may be multiple pathways that can be targeted to leverage goal-relevant attributes during interventions focused on decision making for health.
Discussion and Future Directions

Throughout this paper, we selectively reviewed key neuroeconomic studies that illustrate the value of applying neuroeconomic theory and tools to the study of health choices (for a more comprehensive review, see Table 1). Though the neuroeconomic studies discussed all focus on food as the health relevant stimulus, the insights of these studies can be applied to other health relevant choice. The over representation of food choice relative to other health behaviors is indicative more of the nascent status of this field than it is of a lack of generalizability.

Health psychology, already interdisciplinary in nature, could benefit from neuroeconomic insights into the neurological basis of how choices that form preventative health behaviors are made. Neuroeconomics studies, in turn, can help test and constrain models of decision making that are directly relevant for health behavior. For example, neurobiological models can indicate which parameters in decision models are biologically plausible, thereby improving the accuracy, validity, and applicability of the models. In a parallel way, neuroeconomics can learn from health psychology. At the same time that neuroscience is uncovering the details of how choices are made, there is a dearth of theoretical frameworks that contextualize the mechanisms of the decision process as relevant for health behavior.

While neuroeconomic researchers have begun to incorporate health relevant behaviors into their studies, the full potential of this research to inform preventative health models is as yet unrealized. What is needed to “translate up” is the unification of rich theoretical content from health psychology and investigation by neuroeconomic researchers of the decision making
process during health relevant choices. A partnership between health psychologists and neuroeconomic researchers can yield valuable insights into how preventative health choice is made and to identify targets and methods for intervention.

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Table 1. *Neuroeconomic Studies of Preventative Health Behavior*

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<td>fMRI</td>
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<td>Hare et al., 2008</td>
<td>Binary gain/loss purchasing task</td>
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<td>Harris, Clithero, &amp; Hutcherson, 2018</td>
<td>Dietary choice for self and other</td>
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<td>Condition 2</td>
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<td>Harris, Hare, &amp; Rangel, 2013</td>
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<td>Forced choice with variable probability of reward</td>
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<td>Food &amp; “organic” labeling</td>
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<td>Monetary Choice Questionnaire</td>
<td>Tobacco &amp; money</td>
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<td>VS</td>
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Abbreviations for brain regions are as follows: Anterior cingulate cortex (ACC); Anterior insular cortex (aINS); Dorsolateral prefrontal cortex (dlPFC); Inferior frontal gyrus (IFG); Medial orbitofrontal cortex (mOFC); Middle temporal gyrus (MTG); Posterior cingulate cortex (PCC); Superior frontal gyrus (SFG); Ventral striatum (VS); Ventromedial prefrontal cortex (vmPFC). Sample sizes reported are for the sample analyzed. Hutcherson, Bushong, & Rangel, 2015.
Figure 1. Choice is conceptualized as a hub that connects models of health behavior through a common decision making process.
Figure 2. Neuroeconomics applies neuroscience methods to decision research from psychology and behavioral economics. Only those interconnections between fields minimally necessary to trace the emergence of neuroeconomics and health psychology (solid arrows) and to show the area of potential generativity between them (dotted arrows) are shown.
Figure 3. In the left panel, because the weight of the downsides is greater than that of the rewards, the decision maker would decide against getting a flu shot. For an individual who highly values their health, the attribute related to decreased flu severity may be weighted more heavily, making the total value of vaccination greater for them. For that person, considering these same attributes could result in a different outcome. If the attributes under consideration were to change, such as if the individual discovers that their insurance fully covers the cost of a flu shot thereby removing cost from consideration, and if they discover that the pharmacy at which they are already picking up a prescription offers flu shots on site and without delay, the decision can shift, resulting in a different outcome, in this case resulting in a decision to be vaccinated against the flu as in the panel on the right.
Figure 4. A simple drift diffusion model for binary choice. In the simple model depicted above, evidence for or against a decision accumulates via integration of stimulus values and action costs, generating a noisy action value signal that is tracked by the comparator process (right). The starting point of the decision process can be biased in favor of an outcome by the distance between the upper and lower thresholds (perforated lines) relative to the start point (blue arrow). Response time (RT) is also impacted by non-decision process such as perceptual processing or memory retrieval.  