ARTICLE IN PRESS

JCPS-00264; No. of pages: 19; 4C:

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Journal of Consumer Psychology xx (2012) xxx – xxx

Journal of CONSUMER PSYCHOLOGY

Branding the brain: A critical review and outlook

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Received 2 February 2011; received in revised form 28 November 2011; accepted 30 November 2011

Abstract

The application of neuroscience to marketing, and in particular to the consumer psychology of brands, has gained popularity over the past decade in the academic and the corporate world. In this paper, we provide an overview of the current and previous research in this area and explain why researchers and practitioners alike are excited about applying neuroscience to the consumer psychology of brands. We identify critical issues of past research and discuss how to address these issues in future research. We conclude with our vision of the future potential of research at the intersection of neuroscience and consumer psychology.

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Keywords: Consumer neuroscience; Neuromarketing; Branding; Attention; Memory; Value

Introduction

The application of neuroscience to consumer psychology, and in particular to branding, has gained popularity over the past decade in academic research and business practice: in the last decade the number of publications in top marketing journals and Google references around this topic has grown exponentially and the same holds for the number of neuromarketing companies founded (see Fig. 1).

The birth of the field of consumer neuroscience has generated wide-ranging, ongoing debates of whether this hybrid field benefits its parent disciplines (consumer psychology and neuroscience) and, within them, what forms these benefits might take (Ariely & Berns, 2010; Kenning & Plassmann, 2008; Lee, Broderick, & Chamberlain, 2007; Plassmann, Ambler, Braeutigam, & Kenning, 2007). The goal of consumer neuroscience is to adapt methods and theories from neuroscience—combined with behavioral theories, models, and tested experimental designs from consumer psychology and related disciplines such as behavioral decision sciences—to develop a neuropsychologically sound theory to understand consumer behavior.

To appreciate the value of combining neuroscience with consumer psychology, it is important to understand the broad range of insights available from neuroscience. Neuroscience is the study of the nervous system that seeks to understand the biological basis of behavior. This range of insights is too broad for the study of consumer psychology, which is why in the following paragraphs we briefly clarify which areas within neuroscience are the most relevant for consumer neuroscience.

Neuroscience research ranges from studying single cells (cellular neuroscience) to studying how different brain areas or complex brain systems, such as the visual system, interact (systems neuroscience). Because of the complexity of consumer behavior,

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doi:10.1016/j.jcps.2011.11.010

Please cite this article as: Plassmann, H., et al., Branding the brain: A critical review and outlook, *Journal of Consumer Psychology* (2012), doi:10.1016/j.jcps.2011.11.010

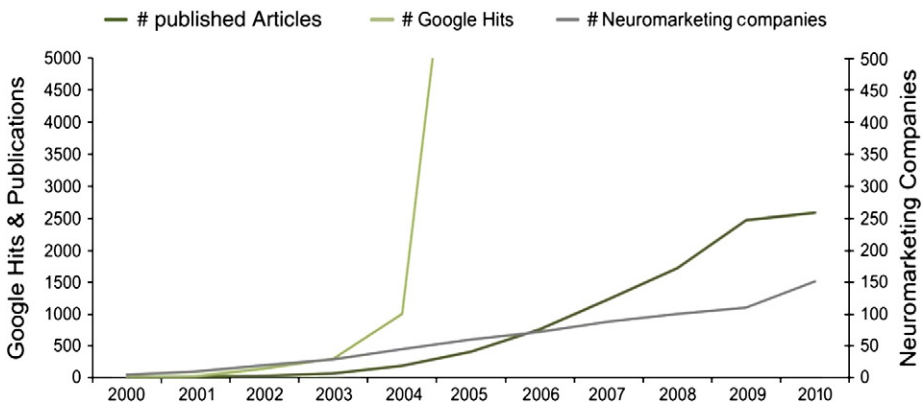

Fig. 1. Growth of research applying neuroscience to marketing over time.

insights from systems neuroscience are crucial for consumer neuroscience, whereas those from cellular neuroscience currently are limited.

Neuroscientists study species ranging from the primitive (such as sea snails, fruit flies, and leeches) to the complex (such as mammals and primates). Most consumer neuroscience studies investigate mental processes in human subjects, but a few selected studies also use non-human primates or small animals such as monkeys as subject populations.[1]

Another important distinction is between clinical and non-clinical research in neuroscience. Clinical research, known as neurology, studies how nervous system disorders, trauma, tumors and injuries affect cognition, emotion, and behavior in patients as compared to healthy subject populations. In general, consumer neuroscience studies consumer responses in healthy subject populations.[2]

A last critical distinction is between consumer neuroscience, which refers to academic research at the intersection of neuroscience and consumer psychology, and neuromarketing, which refers to practitioner and commercial interest in neurophysiological tools, such as eye tracking, skin conductance, electroencephalography (EEG), and functional magnetic resonance imaging (fMRI), to conduct company-specific market research. Neuromarketing has received considerable attention in the corporate world, and the growth of neuromarketing companies over the last decade has been impressive (see Fig. 1).

The goal of this paper is to shed light on what neuroscience can bring to the table to advance our understanding of the consumer psychology of brands. In particular, we aim to provide an overview of the current state of research in this area, identify critical issues of past research and discuss how to address these issues in future research. We conclude with our vision of the future potential of research at the intersection of neuroscience and consumer psychology.

What is currently done: toward an interdisciplinary understanding of consumer decision making

In this section, we review previous work in neuroscience pertinent to understanding underlying processes involved with brand decisions. We structure the review using a simple consumer decision-making framework based on prior work in consumer psychology (Fig. 2; Kahneman & Snell, 1992; Kahneman, Wakker, & Sarin, 1997; Rangel, Camerer, & Montague, 2008; Wirtz, Kruger, Scollon, & Diener, 2003). We also use this framework to integrate previous consumer neuroscience studies that are directly related to branding questions and to point the way for future applications in consumer research.

The framework divides the stages that are required for brand preference formation over time into four basic components: (1) representation and attention, (2) predicted value, (3) experienced value, and (4) remembered value and learning. Below we explain these basic components and review previous findings on the underlying neuropsychological processes of each of those components. The main brain areas involved with each component of the model are shown in Fig. 3.

Representation and attention

The amount of information consumers are exposed to is enormous, yet our processing capacity is limited. Each second we are exposed to an estimated 11 million bits of information that reach us through all our senses, yet humans are capable of processing only around 50 bits of that information, letting most of the input go by unnoticed (Wilson, 2002). How consumers represent, attend to, and perceive incoming information may have a profound influence on their behavior. In the current section, we discuss representation (i.e., brand identification) and attention.

[1] There are at least two major reasons to study non-human subjects in consumer neuroscience. First, studying animals allows consumer neuroscientists to make causal links between brain areas and specific behaviors. Animal work allows the application of more invasive methods to brain systems that animals and humans have in common. Second, if consumer neuroscience researchers are using evolutionary theories to explain phenomena in consumer behavior such as behavioral biases, using an animal model allows evolutionary inferences (i.e., going back in the evolutionary chain).

[2] However, there are several reasons to use patient populations in consumer neuroscience. The most prominent one is to use patients with brain lesions to establish causal relationship between brain regions and consumption behavior. At the end of this paper, we will discuss some of these aspects as potential future developments.

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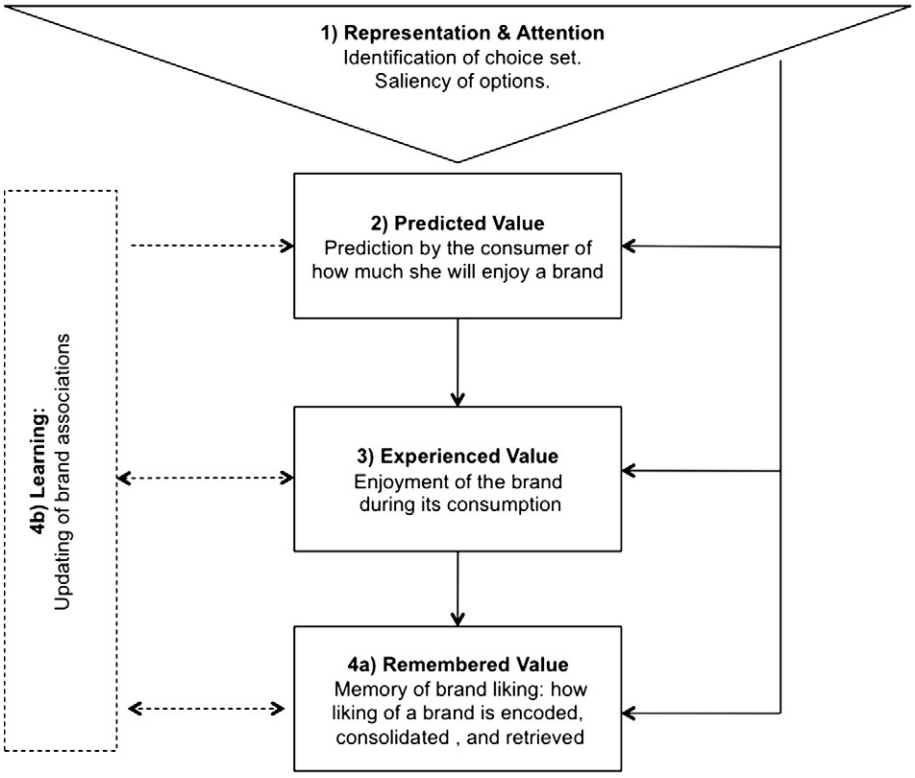

Fig. 2. Value signals important for brand decisions.

Representation The first process in brand decisions involves forming the representation of the choice alternatives—that is, brand identification. This entails processing the incoming information, so that different options for choice are identified (e.g., different beer brands). At the same time, the consumer needs to integrate information on internal states (e.g., thirst level) and external states (e.g., location, social context) that drive attention. For example, when faced with a choice between drinking Heineken or Beck's beer (an incoming information) a consumer's choice is likely to depend on her own level of thirst (an internal state) and what her friend chooses to drink (an external state).

Humans are predominately visual creatures, and most of the incoming information we receive is visual (Koch, 2004). Our visual system contains two cortical routes that are involved with visual processing (see Fig. 3). The dorsal visual pathway is involved with the spatial deployment of attention (the "where/how" pathway) and proceeds from the primary visual cortex V1 in the occipital lobe, through the posterior parietal cortex, to the dorsolateral prefrontal cortex (dlPFC). The ventral visual pathway is responsible for object recognition (the "what" pathway) and originates in V1, then continues to the inferotemporal cortex, and to the ventrolateral PFC.

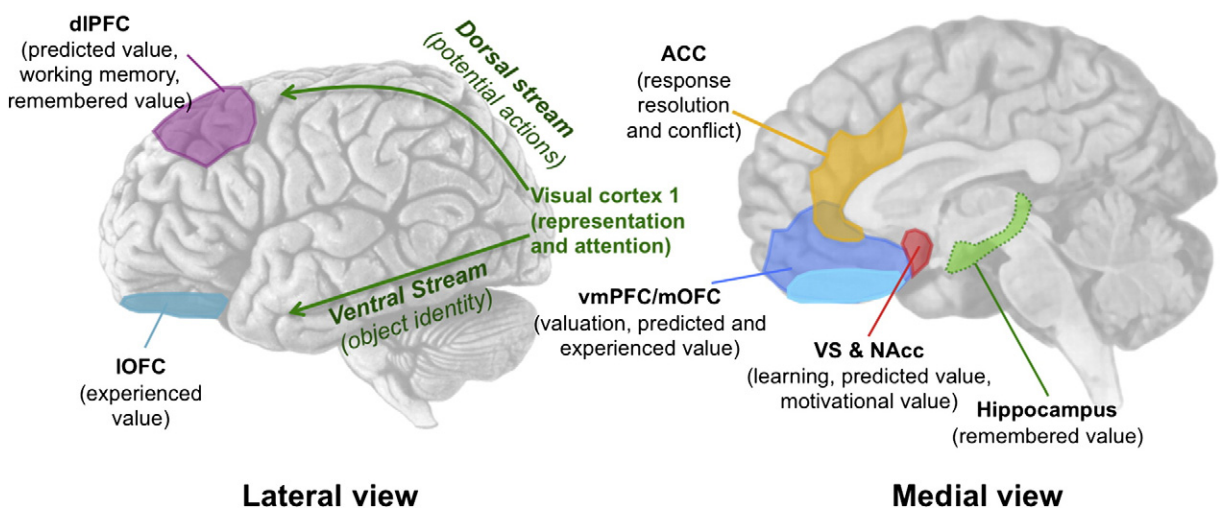

Fig. 3. Overview of prominent brain areas involved in brand decisions.Abbreviations used: ACC = anterior cingulate cortex; dlPFC = dorsolateral prefrontal cortex; lOFC = lateral orbitofrontal cortex; mOFC = medial orbitofrontal cortex; NAcc = nucleus accumbens; vmPFC = ventromedial prefrontal cortex; VS = ventral striatum.

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The visual system allows for rapid brand and product identification. A recent magnetoencephalography (MEG) study showed that female participants viewing shoes (compared to motorcycles) had stronger activity in occipitotemporal regions between 130 and 180 ms after image presentation (Junghoefer et al., 2010). Similarly, Milosavljevic, Koch, and Rangel (2011) showed that consumers can identify two different food brands and make up their mind about which one they prefer in as little as 313 ms. Furthermore, processes involved in the representation stage need not even be conscious, as recent studies have demonstrated that unconscious processes also shape how we represent our decision-making situations (Chartrand, Huber, Shiv, & Tanner, 2008). One of the key questions at this stage, discussed next, is what consumers pay attention to (i.e., focus on) once they are exposed to a number of rapidly identified choice alternatives (i.e., brands).

Attention Attention is the mechanism responsible for selecting the information that gains preferential status above other available information. Recent review of attention in neuroscience indicates that four conceptual components are fundamental to attention: bottom-up or saliency filters, top-down control, competitive visual selection, and working memory (Knudsen, 2007). We will focus on the first three components and discuss their relevance for research on branding.

Bottom-up or saliency filters automatically select the most important information from all available information. This selection is based on the low-level features of the visual input: colors, luminance, orientation, size, shape, movement, etc. (Itti, Koch, & Niebur, 1998; Wolfe & Horowitz, 2004). Such bottom-up factors have a strong effect on the initial eye movements when consumers are exposed to marketing information: the first four eye-movements are made within the initial 2.5 s of exposure (Leven, 1991). Some higher-level factors are also capable of gaining automatic, preferential access to attention. These include faces, text, novelty, and one's own name.

All of these features are combined in the brain, and preattentional scan paths are created, making a saliency map of the regions in the visual field that are most important and thus most likely to be further processed.

Thus, at the outset of early attention, the decision maker is biased toward salient stimuli (van Zoest, Donk, & Theeuwes, 2004). The salient stimuli will attract the initial eye movements of consumers, and thus may have a profound effect on related consumer behavior.

For example, Pieters and Wedel (2007) showed that ensuring that consumers pay attention to the brand displayed in a print ad is the most effective way to ensure that they will transfer their attention to other elements of the print ad. Further, Milosavljevic and colleagues showed that salient features (i.e., the brightness of the food packaging) influence real food choices (Milosavljevic, Navalpakkam, Koch, & Rangel, 2011). Namely, at fast decision speeds a significant number of food choices were biased toward the food items with brighter packaging, even when subjects preferred the taste of alternative food options.

There are other automatic biases known to influence what people pay attention to (Glaholt, Wu, & Reingold, 2010). For example, people tend to look toward the upper visual field (Durgin, Doyle, & Egan, 2008) and the right visual field (Efron & Yund, 1996), which may be of importance in the consumer behavior context (e.g., at the point of purchase). In a famous experiment, when five identical stockings were displayed horizontally, subjects were biased toward choosing stockings on the outmost right (Nissbet & Wilson, 1977). Chandon and colleagues showed that only the top-shelf positions carry through to brand evaluation (Chandon, Hutchinson, Bradlow, & Young, 2009). Clearly, products can be placed in locations that are known to attract more attention and will thus be more likely to be chosen by a buyer (Pieters & Warlop, 1999).

Strong location effects were also found when consumers browse websites (Dreze & Hussherr, 2003). The influence of bottom-up factors may be especially strong online, as consumers engage in fast web surfing and often spend very little time on any given page. Systematically manipulating low-level visual features to "guide" viewers' eyes to a webpage's regions of interest is possible by utilizing insights from visual neuroscience. Milosavljevic (2009) used a computer simulation of visual attention to optimize banner ads, and the rest of a website, to make certain brands/banner ads visually salient. This manipulation resulted in an increased liking for the target banner ad, perhaps due to mere exposure effects (Milosavljevic & Cerf, 2008). Recently, a strong bias of looking toward the center of the viewing area (e.g., the center of the computer screen) has been reported (Tatler, 2007). Reutskaya and colleagues showed that an item in the center of the screen was almost 60% more likely to be chosen by a decision maker than similar items displayed at other locations (Reutskaya, Nagel, Camerer, & Rangel, 2011).

Top-down control depends on internal and external states, goals, and expectations. Hence, looking for a can of Coke will enhance processing of red areas in visual input by increasing the neuronal sensitivity for that particular color (Theeuwes, 2010; Treisman & Gelade, 1980; Van der Lans, Pieters, & Wedel, 2008). Expectation can modulate what consumers pay attention to via brain structures that include the dorsolateral cortex (Egidi, Nusbaum, & Cacioppo, 2008). The information that is relevant for goal attainment will be attended to more than irrelevant information. For example, when we are thirsty, we pay more attention to drinks than to other items (Aarts, Dijksterhuis, & De Vries, 2001; Dijksterhuis & Aarts, 2010).

Goals also exert a strong influence on eye-movements and can result in different eye-movement patterns when subjects are exposed to the same visual input (Glaholt et al., 2010; Pieters & Wedel, 2007; Yarbus, 1967). Rosbergen, Pieters, and Wedel (1997) identifed tendencies in how individuals scan marketing materials, such as print ads or store shelves. Their work was based on a well-established idea of visual scan paths, that is, the patterns of saccades and fixations across some visual input (Norton & Stark, 1971). They found three types of eye movements that are characteristic of people

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examining the ads: scanning (eyes move to headline and pictorial), initial (eyes move to headline, pictorial, and brand), and sustained (eyes move to headline, pictorial, brand, and text). As one might expect, the time spent viewing the ad, the level of involvement, brand attitude, and recall all improved from the first to the third type of viewing. Further, Pieters and Wedel (2007) showed that the informativeness of ads is contingent on the goals consumers pursue while viewing them. For example, in comparison with free viewing of the same ads, consumers spend more time on the text when asked to evaluate the brand, and less time on pictorial elements when asked to learn about the brand.

Visual selection occurs when the most important information from all the areas that are identified as potentially important in preattentive scans (based on the bottom-up input) is chosen. This means that attention is given to a particular location in space. It is believed that as the number of choice options increases, the decision maker becomes more selective in what information he or she encodes, that is, which locations in the scene he or she processes (Payne, Bettman, & Johnson, 1993).

Glaholt et al. (2010) showed that when asked to choose the most expensive of six items (6-alternative-forced-choice, or 6-AFC), subjects were more selective in the processing of stimulus information (i.e., they achieved greater differentiation between individual stimuli via more fixations, longer duration of total fixations, etc.) than when they were asked to choose which of the two sets of three items (2-AFC) was more expensive. Thus, gaze selectivity increases as the number of alternatives increases (Glaholt et al., 2010). Reutskaya et al. (2011) showed that time pressure induced people to shorten the duration of their fixations and to search somewhat longer so as to increase the number of options that are considered before making a choice.

Visual selection and eye movement enhance the quality of incoming information. Gaze bias shows that people spend longer time examining (i.e., fixating on) options that they eventually choose (Glaholt & Reingold, 2009; Krajbich, Armel, & Rangel, 2010; Pieters & Warlop, 1999; Shimojo, Simion, Shimojo, & Scheier, 2003). For example, consumers spent 54% more time looking at the ads of businesses (in a phone directory) that they ended up choosing (Lohse, 1997). It is especially interesting to note that externally manipulating what people look at—for example, by displaying choice options one at a time while manipulating the exposure duration—biases the resulting choices toward the options subjects are exposed to longer (Armel, Beaumel, & Rangel, 2008).

Further, eye movements may be useful in evaluating the effectiveness of brand extensions. Stewart, Pickering, and Sturt (2004) showed that consumers spend 200 ms longer examining implausible brand extensions (they cause immediate disruption of visual processing) compared to plausible brand extensions. The authors propose eye-tracking as a useful tool for determining the extent to which consumers find different brand extensions plausible.

In sum, representation and attention are complex processes that influence all subsequent steps in our brand decisions framework. Theoretical and methodological insights from neuroscience can prove especially useful in allowing consumer researchers to better understand attention and its effects on branding-related behavior. However, research in this area has received little attention in consumer neuroscience, which offers a lot of potential for future research.

Predicted value

The predicted value of each brand that is available for choice (e.g., Heineken vs. Beck's) represents the consumer's belief about the experienced value of that brand at some time in the future. In other words, the predicted value involves the consumer's evaluation of how much enjoyment she will derive from consuming a Heineken or a Beck's beer.

Previous studies suggest that at least three brain structures might be of particular importance when consumers evaluate predicted values: the striatum, the ventral medial prefrontal cortex (vmPFC), and the dorsolateral prefrontal cortex (dlPFC; see Fig. 3). In the next sections, we first review these previous studies and then review studies that have investigated how branding influences predicted value signals in each respective brain region. For the latter we use Keller's customer-based brand equity framework to categorize the different studies (Keller, 1993). Applying Keller's framework, we distinguish between studies investigating how favorableness, type, and uniqueness of brand associations alter the neural signatures of predicted value (see Table 1). Fig. 4 visualizes the results of the studies listed in Table 1 and shows which brain areas are involved in representing Keller's framework in the brain.

Predicted value signals in the striatum Several studies have used functional magnetic resonance imaging to investigate the predicted value of products or other types of desirable objects such as money. Pioneering work by Knutson and colleagues showed that a structure within the ventral striatum (VS), the nucleus accumbens (NAcc), is involved in encoding anticipated rewards of monetary payoffs (Ballard & Knutson, 2009; Knutson, Adams, Fong, & Hommer, 2001; Knutson & Cooper, 2005; Talmi, Dayan, Kiebel, Frith, & Dolan, 2009) and branded products (Knutson, Rick, Wimmer, Prelec, & Loewenstein, 2007; Knutson et al., 2008).

Two studies investigated how favorableness of brand associations affects predicted value signals in the striatum. In the first one, Schaefer and Rotte (2007a) found that imagining a pleasant experience, such as driving a car of a brand that is linked to favorable brand associations, correlates with activity changes in that brain area. However, it remains unclear what exactly consumers were imagining and whether activity in the striatum is based on the difference in pleasantness of the predicted experience per se or the difference in brand information. This weakness of the study is further confounded by the fact that the more attractive car brands are also more expensive, and driving an expensive car might be a pleasurable experience by itself.

One problem with using a given brain activation (the striatum) to infer a mental process (a pleasurable experience) is the proposed one-to-one relationship between the brain activity and the mental process of interest. Such a "reversed inference" is problematic because one brain area is usually involved in more than one mental process (for a detailed discussion of the "reverse

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Table 1
Overview of consumer neuroscience studies directly related to branding.

Branding area	Author	Main question	Method	Main results
Favorability of brand associations	Deppe, Schwindt, Kugel, Plassmann, and Kenning (2005)	What brain areas correlate with brand preference?	fMRI	When choosing between one's favorite brand as compared to a second or lower ranked brand increased activity in the vmPFC and reduced with activity in dlPFC/IFG and visual cortex (cuneus/precuneus) are triggered.
	Deppe, Schwindt, Kramer, et al. (2005)	What are the underlying neural processes of how brand information bias semantic product judgments?	fMRI	Activity in the ACC predicted whether a person is biased by the brand name of a newspaper while evaluating the credibility of a headline.
	Deppe et al. (2007)	What are the underlying neural processes of how brand information bias visual product judgments?	fMRI	Activity in the ACC predicted whether a person is biased by the brand name of a newspaper while evaluating the attractiveness of print advertisements.
	Schaefer and Rotte (2007a)	What are the neural correlates of brand preferences during (imagined) consumption?	fMRI	Imagining driving a car from one's favorite brand correlates with activity changes in the ventral striatum. Activity in this area also correlates with perceived luxury and sportiness of the car.
	Koenigs and Tranel (2008)	What is the role of the vmPFC for how brand information biases preference judgments?	Lesion-study	Patients with damage in the vmPFC were not biased by brand information during blind vs. open tasting of Coke and Pepsi.
	Plassmann et al. (2008)	Does uncertainty modulate the neural signatures of brand preference?	fMRI	Interaction of brand preference with uncertainty of the decision amplifies the neural correlate of brand preference in the vmPFC.
Different types of brand associations	Erk et al. (2002)	What are the neural correlates of preferences for product types that are vs. low in social status signaling?	fMRI	Sports cars vs. limousines induced increased activity changes in the brain areas involved in reward processing (striatum, vmPFC/mOFC and ACC).
	Schaefer and Rotte (2007b)	Does high social status signaled by brands trigger the same responses than low social status signals?	fMRI	• Car brands signaling high social status activated regions in the MPFC and precuneus. • Car brands signaling low social status activated the left superior frontal gyrus and ACC
	McClure et al. (2004)	What are the underlying brain processes of how brand information alters brand evaluations during consumption?	fMRI	Stated preferences for Coke vs. Pepsi did not correlate with revealed preferences in blind tastings Revealed preference correlated with activity changes in the vmPFC/mOFC Knowing you drink Coke vs. not knowing what you drink correlated with activity changes in memory/association areas (hippocampus, dlPFC/SFG). No such difference could be found for the case of Pepsi
	Yoon et al. (2006)	Do brand judgments recruit the same neural networks as judgments about people?	fMRI	Brain areas involved in making judgments about human traits for people do not overlap with brain areas involved in making judgments about human traits for brands.
Brand recall and memories	Schaefer et al. (2006)	What are the neural correlates of brand familiarity?	fMRI	Activity changes in the MFG correlate with familiar vs. unfamiliar brands
	Klucharev et al. (2008)	How does the expertise of an endorser affect brand memory and attitude?	fMRI	Increased brand recall for expert endorsement was related to stronger activation during encoding of memory structures of the left hemisphere, the dlPFC and medial temporal lobe structures, and accompanied by stronger engagement of the bilateral striatum.
	Esch et al. (in press)	What are the neural correlates of brand familiarity and brand "strength"	fMRI	Unfamiliar brand logos vs. "strong" brands induce activity changes in the IFG "strong" vs. unfamiliar brands induce activity changes in the hippocampus and lingual gyrus "strong" vs. "weak" brands induce activity changes in the dlPFC/MFG
Brand loyalty	Plassman, Kenning, and Ahlert (2007)	Do loyal customers recruit other brain areas than disloyal customers during brand choice?	fMRI	Activity in the striatum correlates with brand loyalty to retail brands.

Note: The table includes studies that uncover brain areas involved in different topics related to branding that allow making inferences about locations in the brain. We did not include studies investigating temporal dynamics, such as techniques with a high temporal resolution such as EEG/MEG.
Abbreviations used: ACC = anterior cingulate cortex; dlPFC = dorsolateral prefrontal cortex; IFG = inferior frontal gyrus; mOFC = medial orbitofrontal cortex; vmPFC = ventromedial prefrontal cortex.

inference problem" in consumer neuroscience studies see below). A potentially interesting direction for further studies in this area is to manipulate the expected pleasantness of the consumption experience (e.g., a road trip vs. commuting in heavy traffic) and investigate how this is altered by brand information while controlling for price levels.

The second study, by Plassmann, Kenning, and Ahlert (2007), found that when choosing between buying identical

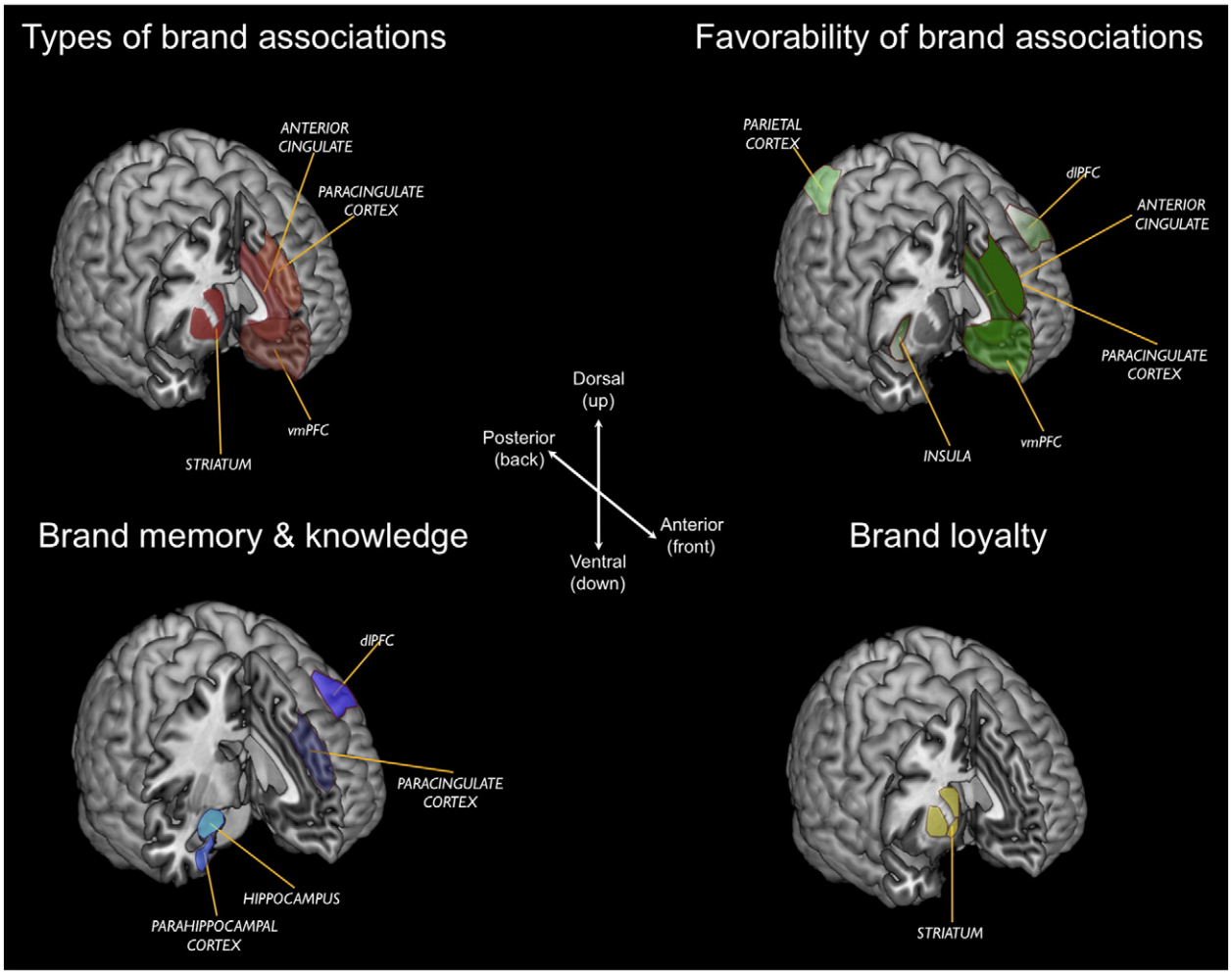

Fig. 4. Overview brain systems involved in the psychology of brands.Note: this figure shows a three-dimensional view of the brain and it is important to note that the front (anterior) to back (posterior) slice view shown differs between the different parts of the figure, i.e. a view showing the hippocampus is more posterior than views showing the striatum; Abbreviations used: dlPFC = dorsolateral prefrontal cortex; vmPFC = ventromedial prefrontal cortex.

clothes at different retail stores (e.g., H&M vs. Zara), customers who are loyal to a store as measured by real purchasing behavior (i.e., amount spent, frequency and recency of purchases based on loyalty card data) show more activation in the striatum compared to customers who are less loyal. Although this study provides an interesting and methodologically valuable link between real-life purchasing behavior outside the lab (i.e., based on scanner data at the point of sale) and brain activation by inviting loyalty card holders to the brain imaging lab, one potential confound of this study is the passive choice paradigm applied in the study. In the passive choice paradigm test persons were not required to respond, i.e. make choices inside the scanner. Instead, behavioral measures were taken outside the scanner. The lack of these response measures results in missing important manipulation checks. This is further linked to the above-mentioned problematic reliance on reverse inference.

To the best of our knowledge, no study to date has investigated the impact of the different types of brand associations or uniqueness of brand associations on predicted value signals in the striatum. This calls for further research in this area.

Predicted value signals in the ventromedial prefrontal cortex (vmPFC) and the dorsolateral prefrontal cortex (dlPFC) Another series of human fMRI studies has studied predicted values using real choices and has found that neural activity in the vmPFC correlates with behavioral measures of consumers' positive and negative predicted values for a range of different branded products (Chib, Rangel, Shimojo, & O'Doherty, 2009; Hare, O'Doherty, Camerer, Schultz, & Rangel, 2008; Plassmann, O'Doherty, & Rangel, 2007; Plassmann, O'Doherty, & Rangel, 2010) and also in a social context when making decisions about charitable donations (Hare, Camerer, Knoepfle, & Rangel, 2010).

Most of the abovementioned studies found that a brain system consisting of the vmPFC and the dlPFC encodes behavioral preferences (Camus et al., 2009; Plassmann et al., 2007; Plassmann et al., 2010; Wallis & Miller, 2003). Importantly, in Camus et al.'s (2009) study, test subjects were "virtually lesioned" in the dlPFC using transcranial magnetic stimulation (TMS) and showed a change in behavioral measures of predicted values.

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Several consumer neuroscience studies have investigated how brand associations alter predicted value signals in the vmPFC and dlPFC as well as in related brain areas. Some of these studies investigated how brand favorableness influences neural signatures of predicted value signals; other studies compared how different types of brand associations alter those signals.

A series of studies by Deppe and colleagues investigated how favorableness of brand associations influences predicted value signals in the brain. In the first study, the authors found increased neural activity in the vmPFC when the choice set contained the consumer's favorite brand compared to choice sets containing two less preferred brands. They also found that the part of the dlPFC involved in working memory and the part of the visual system involved in object recognition were less active when the choice set contained the consumer's favorite brand compared to a set containing two non-preferred brands (Deppe, Schwindt, Kugel, Plassmann, & Kenning, 2005). A potential confound of this first study is the passive choice design that did not allow the recording of choices and reaction times. In other words, no actual behavioral choices were recorded, but preference rankings were sampled at the end of the experiment outside the scanner. These measures could have served as important manipulation checks and would have avoided having the results rely on reversed inference, discussed below.

In two follow-up studies the authors applied an active choice task and replicated their finding that the vmPFC correlated with favorableness of brand associations (Deppe et al., 2005; Deppe et al., 2007). Interestingly, in these follow-up studies, the authors showed that the degree to which a brain area involved in selective attention and conflict monitoring (the anterior cingulate cortex, ACC; see Fig. 3) is correlated with the degree of how much consumers' judgments are biased by brand associations (Deppe, Schwindt, Kramer, et al., 2005; Deppe et al., 2007). In other words, these two studies suggest that ACC activity predicts individual differences of how much brand associations influence consumers' judgments.

A more recent study by Esch et al. (in press) also investigated how favorableness of brand associations influences brain activity during brand decisions. They found that the part of the dlPFC involved in predicted value encoding is more active when consumers are exposed to "strong" vs. "weak" brands. They also found that exposure to "weak" vs. "strong" brands leads to more activity in the insula, the brain area previously found to encode disgusting, painful, or more generally intense and arousing emotional experiences. However, because the reported results are based on a very low statistical threshold not corrected for multiple comparisons (i.e., .005) or for cluster levels (i.e., small volume corrections or region of interest analysis) that are typically not reported as core findings in neuroscience journals, the study by Esch et al. awaits further empirical validation.

Several studies have investigated how different types of brand associations influence predicted value signals in the vmPFC, dlPFC, and related areas. Most of the studies look at brand associations linked to cultural influences and social status. Studies by Erk, Spitzer, Wunderlich, Galley, and Walter (2002) and Schaefer and Rotte (2007a) found that exposure to branded products associated with high social status induces activity changes in the vmPFC, ACC, PFC and striatum. For both studies it remains unclear whether the type of brand association (i.e., high vs. low social status) or how much people like the brand (i.e., favorableness of brand association) is driving the results because the experimental design does not allow these two factors to be dissociated. As a result, both studies also rely on reverse inference.

A study by Yoon, Gutchess, Feinberg, and Polk (2006) investigated brand personality associations. The authors compared whether judgments about personality attributes of people are represented in the same neural system as judgments about personality attributes of brands and whether this differs when these judgments refer to the self or others. They found that brain areas involved in making judgments about human traits for people do not overlap with brain areas involved in making judgments about human traits for brands. These first findings challenge the view that we associate brands with personalities and are able to form relationships with brands the same way we form relationships with people (Aaker, 1997; Aaker & Fournier, 1995; Aggarwal, 2004; Fournier, 1997; Swaminathan, Page, & Gurhan-Canli, 2007) and call for further research.

To the best of our knowledge, no study has looked at the impact of the uniqueness of brand associations on predicted value signals in the vmPFC and dlPFC to date. This calls for further research in this area.

Experienced value

Experienced value is based on the pleasure derived from consuming a brand. According to early notions of utility or value, experienced value is the "true value" that should matter the most for value-based decision making (Kahneman et al., 1997). Experienced value consists of the (a) valence and (b) intensity of the consumption experience. In this section, we first review general and branding-related neuroscientific research investigating valence and intensity of experienced values and then review the neural basis of a concept that connects brain systems involved in representing predicted and experienced value, namely motivational value.

Valence The neural bases of computations made by the evaluation system during the consumption experience are beginning to be understood. Human fMRI studies have shown that activity in the orbitofrontal cortex (OFC), in particular its medial parts (see Fig. 3), at the time a reward is being enjoyed correlates with subjective reports about the pleasantness or valence of the experience. This has been shown for olfactory experiences (Anderson et al., 2003; Kringelbach, O'Doherty, Rolls, & Andrews, 2003; McClure et al., 2004; Small, Zatorre, Dagher, Evans, & Jones-Gotman, 2001; Small et al., 2003), musical rewards (Blood & Zatorre, 2001), visual rewards (Aharon et al., 2001; Kirk, Skov, Hulme, Christensen, & Zeki, 2009), pleasantness of touch (McCabe, Rolls, Bilderbeck, & McGlone, 2008), and even secondary rewards such as money (Breiter,

Please cite this article as: Plassmann, H., et al., Branding the brain: A critical review and outlook, *Journal of Consumer Psychology* (2012), doi:10.1016/j.jcps.2011.11.010

Aharon, Kahneman, Dale, & Shizgal, 2001; Knutson, Fong, Adams, Varner, & Hommer, 2001; Knutson, Fong, Bennett, Adams, & Hommer, 2003). Moreover, the activity in the OFC is reduced when consumers are fed to satiety on a specific food (O'Doherty et al., 2000).

Taken together, these findings suggest that the medial OFC might be an area where positive experienced values are computed. Other studies have found that brain areas that receive inputs from the OFC areas, such as the ventral striatum and the pregenual cingulate cortex (Grabenhorst, Rolls, & Bilderbeck, 2008; McCabe et al., 2008; Rolls, Grabenhorst, & Franco, 2009; Rolls & McCabe, 2007), are also correlated with sensory pleasantness.

An interesting open question is which neural systems encode negative experiences. Several studies have found that unpleasantness of taste might be correlated with brain activity in the lateral OFC and left dorsal anterior insula/operculum (Small et al., 2001; Small et al., 2003). O'Doherty and colleagues found that the size of abstract punishments (i.e., losing money) activated lateral parts of the OFC (O'Doherty, Kringelbach, Rolls, Hornak, & Andrews, 2001). One problem in investigating negative experience is to dissociate it from intensity. This problem arises due to the negativity bias of intensity: negative experiences are usually also perceived to be more intense and thus are often confounded (Small et al., 2003), in particular for visual stimuli such as facial or object attractiveness.

Using a different methodological approach to investigate positive vs. negative emotional experiences, neuromarketing studies are based on the idea that there is a left–right asymmetry of the frontal electroencephalography (EEG) signals (Davidson, Ekman, Saron, Senulis, & Friesen, 1990). These and related studies suggest that relatively greater activity in the left frontal region is associated with either positive emotional experience or the motivational drive to approach an object (Harmon-Jones, 2003). Although there are strong correlations between frontal EEG asymmetry and personality traits, the degree to which the asymmetry changes from one moment to another is questionable. Some studies have applied this approach to measure moment-to-moment fluctuations in emotional responses to advertisements without accounting for autocorrelations in time or multiple statistical comparisons (Ohme, Reykowska, Wiener, & Choromanska, 2009). However, the validity of such approaches is unclear, as hemispheric asymmetry is also an index of working memory load (Habib, Nyberg, & Tulving, 2003; Tulving, Kapur, Craik, Moscovitch, & Houle, 1994). Further research to investigate the neural representation of positive vs. negative experienced values is needed.

Several recent human fMRI experiments have provided novel insights into how marketing actions such as branding might alter the properties of the experienced value signals. For example, one study showed that activity in the medial OFC in response to an odor depended on whether subjects believed that they smelled cheddar cheese or body odor (de Araujo, Rolls, Velazco, Margot, & Cayeux, 2005). In another study, activity in the medial OFC in response to the consumption of wine depended on quality beliefs about its price (Plassmann, O'Doherty, Shiv, & Rangel, 2008). Yet another study found that experienced values of works of art, and accompanying engagement of the medial OFC, depended on whether the subjects believed they were created by an expert (i.e., an artist) or by a non-expert (i.e., the experimenter; Kirk et al., 2009). Together, these findings suggest that the experienced valuation system is modulated by higher cognitive processes that determine expectancies and beliefs—a phenomenon recently referred to as the "placebo effects of marketing" actions (Shiv, Carmon, & Ariely, 2005; Waber, Shiv, Carmon, & Ariely, 2008) or "expectation bias" (Plassmann & Niessing, 2010).

To date there is only one study that has investigated how favorable brand associations alter experienced value signals. McClure et al. (2004) investigated differences in brain activity during consumption of sodas when the subjects knew they were drinking Coke or Pepsi vs. when they did not know which brand they were consuming. Unbeknownst to the subjects, they were consuming Coke and Pepsi in both conditions (brand-cued and non-brand-cued trials). The study showed that the experienced value signals depended on brand associations. In particular, the authors found that subjects' knowing they were drinking Coke vs. not knowing what they were drinking correlated with activity changes in their memory/association areas (hippocampus, dlPFC/SFG). No such difference could be found for Pepsi.

An interesting follow-up of this experiment would be to have four different types of trials. In two types of trials Coke would be administered, once cued with a Coke logo and once cued with a Pepsi logo. In the other two types of trials Pepsi would be administered, once cued with a Pepsi logo and once cued with a Coke logo. This would help to dissociate the role of brand information for preference encoding from memory functions linked to retrieving the brand associations.

A similar version of the above-suggested experiment has been done using a different methodological approach, namely using patients with brain damage or lesions in a specific brain area, here the vmPFC. Koenigs and Tranel (2008) investigated how preferences for Coke vs. Pepsi in patients with damage in the vmPFC changed during blind vs. open tasting of both sodas. They found that brand associations in the open tasting did not influence the lesion patients, only the control patients. In other words, patients with a lesioned vmPFC did not reverse their preferences when they knew what brand of soda they were consuming. To better understand the roles of the regions reported by McClure et al. (2004), similar studies should be conducted on patients with injury to the dorsolateral PFC and hippocampus. The advantage of using lesion patients as compared to fMRI is that causal and not "only" correlational links between mental processes and brain functioning can be established.

Intensity Another, much smaller stream of research has investigated the intensity of emotional and sensory experiences: In humans, subjective reports of pain intensity correlated with

activity in the insula and the ACC (Davis, Taylor, Crawley, Wood, & Mikulis, 1997; Peyron et al., 1999). Recent studies in the chemosensory domain found that amygdala activity increased with the intensity of negative and positive chemosensory stimuli (Anderson et al., 2003; Small et al., 2003). Several studies by Berns and colleagues suggest that the saliency or intensity of objects such as sound and money correlate with neural activity in the dorsal and ventral striatum (Zink, Pagnoni, Chappelow, Martin-Skurski, & Berns, 2006; Zink, Pagnoni, Martin, Dhamala, & Berns, 2003; Zink, Pagnoni, Martin-Skurski, Chappelow, & Berns, 2004). Similar results have been found for the neural correlates of flavor intensity vs. flavor pleasantness (Small et al., 2003). To the best of our knowledge no studies to date have investigated how brand associations influence the intensity of experienced value signals. In turn, there are a lot of questions open for future research in this area.

Motivational value A concept that is related to how predicted and experienced values interact is the motivational value or incentive salience of an option. Over the past two decades, pioneering work by Berridge and colleagues has contributed to a better understanding of value processing in the brain by distinguishing between "wanting" and "liking" responses to stimuli (Berridge, 2007, 2009a, 2009b; Berridge & Kringelbach, 2008; Berridge & Robinson, 1998). "Wanting" refers to a person's (or animal's) motivation to obtain a given reward, as observed by increased effort, longer viewing times, and stronger grip strength (e.g., Pessiglione et al., 2007). "Liking" refers to the experienced value. This line of research has found an important role of the dopaminergic system for wanting, but not necessarily for liking (Berridge & Kringelbach, 2008; Berridge & Robinson, 1998).

A study by Litt, Plassmann, Shiv, and Rangel (2011) showed that the predicted value signals encoded in the mOFC/vmPFC are not confounded with related saliency signals of the options for choice.

More recently, the distinction between "wanting" and "liking" has also received more attention in consumer behavior research (Brendl, Markman, & Messner, 2003; Litt, Khan, & Shiv, 2010; Morewedge, Huh, & Vosgerau, 2010; Xianchi, Brendl, & Ariely, 2010). However, to date there is no behavioral or neuroscientific research trying to understand how different types of brand associations, and how favorable or unique they are, affect wanting and liking for brands.

Remembered value and learning

Consider again our example of choosing between Heineken and Beck's. An important predictor of your choice is your memory of previous exposures to the two brands. If you remember that Heineken had a bitter taste and Beck's had a distinct whiff of something sweet, these experiences may influence your decision. You may remember a recent entertaining Heineken commercial, but you have no such memory of a Beck's commercial. Brands "work their magic" by associating themselves with experiences, which in turn influence subsequent retrieval and recognition. It is important to note that these can be personal experiences or those of other people—shown in commercials or told by friends through word of mouth.

Remembered value refers to how different brand associations are encoded, consolidated, and retrieved in the consumer's memory. Recent research suggests that parts of these processes happen on an unconscious level. Similar models have been seen in consumer psychology. For example, Van Osselaer and Janiszewski (2001) distinguished between the Human Associative Memory model, a process that was a general and unfocused incidental (or unconscious) associative learning, and an adaptive learning mechanism focusing on feature-benefit associations for future rewards.

Hence, the remembered value consists of both explicit memory and implicit memory of prior consumption experience. In this section, we first review the neuroscientific literature of explicit and implicit memory and learning processes relevant to branding. Following this, we briefly review recent studies on the dynamic nature of brand memories, that is, how explicit and implicit memory changes over time and how external factors such as marketing actions might affect remembered value.

Explicit brand memory Studies have demonstrated that explicit memories—also known as declarative memories—rely on specific brain regions such as the hippocampus and surrounding medial temporal lobe (MTL) region, in synchrony with other brain regions such as the dlPFC (Squire & Zola, 1996a, 1996b, 1998). Indeed, the distinction between declarative and non-declarative memories remains a dominant model for our understanding of memory function (Ramsøy et al., 2009; but see Henke, 2010, for a recent alternative account). Several studies have reported a strong link between memory and preference. In a seminal paper by McClure et al. (2004), it was reported that an increase in preference for the beverage labeled as Coca-Cola, but not the one labeled Pepsi Cola, was paralleled by an activation increase in the hippocampus and the dlPFC. In other words, the brand-induced change in preference was mediated by regions implicated in declarative memory.

Similar activations of the PFC were reported in the aforementioned study by Schaefer, Berens, Heinze, and Rotte (2006) in which subjects were asked to visually imagine driving a car of a well-known car manufacturer (e.g., BMW) or an unknown generic car brand in the German car market at the time the study was conducted (e.g., Acura). That is, while the act of imagining driving a car was equal between the two conditions, imagining driving a well-known car led to a stronger engagement of the superior frontal gyrus of the PFC, which has also been implicated in memory function.

In a recent study by Klucharev, Smidts, and Fernandez (2008) the link between memory and preference was further strengthened by studying how "expert power" influences this link. In the study, products that were presented simultaneously with an expert person were associated with improved recall at a subsequent memory test on a different day. Notably, by using fMRI during expert object presentations, the researchers found activation changes related to successful encoding and subsequent recall. Expert conditions were associated with increased activity in the striatum (both caudate

and likely the ventral striatum/NAcc) and, interestingly, with memory-related activity in the dlPFC, hippocampus, and parahippocampal cortex. Probing the relationship between favorable attitude toward experts and memory performance, the researchers also demonstrated a more direct coactivation of the bilateral caudate nuclei, hippocampus, and parahippocampal cortex. Thus, the link between preference and memory seems to be based on a synergic coactivation of the reward system and memory-related structures such as the dlPFC, hippocampus, and parahippocampal cortex. In another study, Schaefer and Rotte (2007b) demonstrated that brand names or logos engaged the neural reward system, further suggesting that a brand can work as a secondary reinforcer and act on the valuation systems of the brain.

Nevertheless, much is still unknown about the relationship between explicit memory and preference formation, and studies have shown inconsistencies. In another study by Schaefer and Rotte (2007a) it was found that when subjects viewed their most beloved brands, there was a decrease in the activation of both the dlPFC and the hippocampus and an increase in activation in reward regions such as the striatum. Thus, this study may seem at odds with previous suggestions of a positive relationship between memory engagement and preference formation. However, one may contend that the increased activation of memory-related regions found by Schaefer et al. (2006) can be explained by the greater visualization richness when imagining driving a well-known car brand compared to an unknown, generic car. Thus, this complicating factor may be related to differences in study design and other factors, but nevertheless highlights that the neural bases and the basic mechanisms of branding are still poorly understood.

Implicit brand memory As shown by several recent reports during the past few decades, the search for unconscious processes and implicit measures of branding is an active field of inquiry in consumer psychology (Baker, 2003; Bargh, 2002; Brasel and Gips, 2011; Chartrand et al., 2008; Claudi, Dimofte and Yalch, 2011; Friese, Wänke, & Plessner, 2006; Janiszewski, 1993; Moore, 1988; Nevid, 2010; Pratkanis & Greenwald, 1988; Saegert, 1987; Shapiro, 1999; Synodinos, 1988; Theus, 1994; Zajonc & Markus, 1985; Zaltman, 2000). For example Chartrand et al. (2008) demonstrated that subliminally presented retail brand names had an influence on goal pursuit. This suggests that the motivational effect of brands has an unconscious basis.

Although some scholars suggest a more cautious take on the power of the unconscious in the consumer research domain (see Simonson, 2005), recent insights from both behavioral approaches and neuroimaging make it inescapable that brands can be triggered unconsciously or, even when presented overtly, can affect consumer behavior without the person being privy to such effects.

An ongoing debate in cognitive neuroscience concerns the degree to which unconscious stimuli can affect processing in the brain and influence behaviors (Kouider & Dehaene, 2007). Most accounts postulate that low-level computations (e.g., motor reflexes and sensory processing) are driven by unconscious mechanisms, while high-level executive functions such as decision making require consciousness. Yet an increasing body of evidence suggests that higher processing levels can be engaged unconsciously.

Recent studies have demonstrated that the prefrontal cortex, associated with conscious executive functions, can be engaged by subliminal task-switching cues (Lau & Passingham, 2007). For example, Pessiglione et al. (2007) reported that subliminal high-value rewards increased the strength with which subjects deployed effort on a hand grip task relative to low-value rewards. This was related to activation of the ventral striatum (VS), a subcortical reward structure.

Similar findings were made for abstract icons as primes, showing that reward-related activation and learning mechanisms of the VS could operate unconsciously (Pessiglione et al., 2008), and such findings suggest a role for unconscious learning processes in guiding motivated behaviors. From early studies of primates and mammals (Hollerman & Schultz, 1998; Schultz, 1998, 2001; Schultz & Dickinson, 2000) to more recent neuroimaging studies (Brown & Braver, 2007; D'Ardenne, McClure, Nystrom, & Cohen, 2008), value-based learning is now thought to include sub-cortical, low-level brain regions such as the ventral tegmental area, striatum, anterior cingulate cortex, and hippocampus.

Taken together, the implicit brand memories seem to engage both the deeper basic structures of the brain and memory regions previously thought to be dedicated solely to explicit memories. By using new and sophisticated analysis tools on neuroimaging data, it is possible to track neural processes that precede and even predict conscious choice. Such advances not only improve our understanding of implicit brand memory but provide a whole new avenue for studying the consumer psychology of branding.

The dynamic nature of memories Different models of memory retrieval have seen memories as being "replayed," contributing to the popular notion that (episodic) memories are stored as hard copies in the brain. In this view, remembering is the process of retrieving factual and true information about the experiences we have had. While memories have been thought of as labile during encoding, information that is consolidated in memory has been thought to be retrieved as more stable "information packages." Neurobiological studies have recently challenged this notion (Nader, Schafe, & LeDoux, 2000; Schafe, Nader, Blair, & LeDoux, 2001), showing that even powerful memories such as fear conditioning can be altered or eradicated by inhibiting the neural mechanisms (protein synthesis in the amygdala) during retrieval. This suggests that the retrieval stage is an active and dynamic relearning process rather than the mere replay of previously acquired information.

The idea of false memories has been paralleled by research in consumer psychology and behavior. A study by Braun-Latour and Zaltman (2006) demonstrated that advertising can unconsciously alter consumers' beliefs as reflected by a change in how they recalled their earlier reporting of these beliefs following exposure to advertising. A related study by Cowley (2007) also showed that affective reactions derived from post-experience

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information (i.e., advertising) may interfere with the retrieval of experience-based reactions: The results of three experiments showed that when post-experience affective reactions interfere with the retrieval of an experience-based reaction, consumers use post-experience behavior as a proxy for their liking of the experience. In a recent study making use of the dynamic nature of memory, Rajagopal and Montgomery (2011) demonstrated that exposure to an imagery-evoking ad led to a false memory of prior product exposure, further causing alterations in product attitude. Future studies should connect the consumer psychology and neuroscience literatures, and focus on the role and neural bases of dynamic memory in the formation, sustaining, and alteration of brand preferences.

Taken together, this review of "what has been done" shows that interdisciplinary effort in understanding how decision making is represented in the brain has taken off and that these findings can be applied to extend our understanding of the psychology of branding. Our review also points out directions for future research in this area. Two critical issues are important to note:

First, most of the studies reviewed above are mostly exploratory in nature, but have already succeeded in challenging our notions of how branding works. We encourage researchers to go beyond a mere correlation approach, i.e., localizing the neural bases of brand familiarity or brand preference. This type of research is important but contributes mostly to our understanding of the brain while providing fewer novel insights into the psychology of brands. To advance the psychology of branding, we suggest that future work focus more on establishing meaningful brain-behavior relationships that go beyond correlational findings, by combining the neuroscientific tool kit with traditional methods. We make suggestions to address this point in the last section of this paper.

Second, the review in this section pointed out several methodological issues with previous consumer neuroscience studies related to branding that have been published in academic journals. Many additional issues can be raised for unpublished work in the form of commercial applications of neuroscience to the psychology of branding, which has become a business with almost exponential growth. In the next section of the paper we detail the major issues and make suggestions for how to overcome them.

What should not be done: the need of standards for neuroscience work published in marketing journals

How can neuroimaging be a valuable tool for branding researchers? The promise of having a method for opening the "black box" of consumers' brains may seem like a dream come true for any academic or practitioner interested in branding and other areas of consumer behavior. However, as seen in the review above, one can identify at least one major issue that needs the attention of researchers applying neuroscience tools for branding questions and of reviewers of such work: how to overcome the problem of reverse inference.

One practice that has become common in consumer neuroscience studies in general, and those related to branding in particular, is reverse inference, by which the engagement of a particular mental process is inferred from the activation of a particular brain region (Poldrack, 2006). We believe the deductive validity of such inferences is limited.

The inference that is usually drawn from neuroimaging data, according to current scientific standards, is of the form "if cognitive process X (e.g., willingness-to-pay computation) is engaged, then brain area Z (e.g., mOFC) is active." However, previous consumer neuroscience and commercial neuromarketing studies reverse this reasoning, as follows:

- In the current study, when task comparison A was presented (e.g., imagining driving a car branded by a familiar vs. an unfamiliar logo seen on the screen), brain area Z (e.g., the medial prefrontal cortex) was active.
- In other studies, when cognitive process X (e.g., self-reflection and self-relevant thoughts) was putatively engaged, brain area Z (e.g., the medial prefrontal cortex) was active.
- Thus, the activity of area Z (e.g., the medial prefrontal cortex) in the current study demonstrates engagement of cognitive process X (e.g., self-reflection and self-relevant thoughts) by task A (e.g., imagining driving a car branded by a familiar vs. an unfamiliar logo seen on the screen).

This has been referred to as a reverse inference, since it reasons backwards from the presence of brain activation to the engagement of a particular mental process (Poldrack, 2006). The fact that reverse inference is problematic is partly due to the fact that functional brain imaging research is still relatively new, and as a consequence, we do not have a detailed map of the brain to date. More important is the fact that a single brain area can multitask, and that the brain has a built-in redundancy. In other words, one particular brain area could be involved in encoding both brand personality associations and brand familiarity. If a study finds this brain area Z to be involved in brand decisions without implementing a design that allows dissociating between the two, the inference that activity in this area means that one brand is more familiar is of only limited validity.

In many cases the use of reverse inference is informal; the presence of unexpected activation in a particular region is explained by reference to other studies that found activation in the same region. The issue of reverse inference becomes much more problematic when the central findings and contributions of the paper are built on reverse inference. As our review of consumer neuroscience studies related to branding revealed, several of the previous studies in this area (these authors' included) use reverse inference as a central feature to discuss their findings. There are several ways to address the problem of reverse inference in neuroimaging studies.

The first and most straightforward way is to implement an experimental design and data analysis that allow capturing the neural signature of the mental process of interest directly. For example, a recent study investigated how changing the price of wine affects taste processing in the brain (Plassmann et al., 2008). The study found that when subjects consumed the same wine in two experimental conditions, once cued with a

high price and once with a low price, brain activity in the mOFC was affected. Other studies found that this brain area encoded taste pleasantness. The design of the study allowed the authors to run a different data model to check which brain area in their data encoded taste pleasantness. They found that in their data also the mOFC encoded taste pleasantness irrespective of the changes in the price of the wine. Their design and data analysis procedure allowed the authors to control for relying on reverse inference.

The second way to address the reverse inference problem is to find a measure of the degree to which the region of interest is selectively activated by the mental process of interest (Ariely & Berns, 2010; Poldrack, 2006). If, on one hand, a region is activated by a large number of mental processes, then activation in that region provides relatively weak evidence of the engagement of the mental process. If, on the other hand, the region is activated relatively selectively by the specific mental process of interest, then one can infer with substantial confidence that the process is engaged given activation in the region. The idea is to compute a selectivity factor that determines the posterior probability for the reverse inference using Bayesian statistics based on previous findings (see Poldrack, 2006 for details).

However, there are at least two important concerns. First, although Poldrack's procedure to compute a selectivity factor is meaningful in a statistical sense, the assumptions behind such a calculation are rather liberal and may suffer from a publication bias for positive results. Second, the mental process of interest needs to be specified very precisely for an application of this idea to consumer neuroscience. "Reward processing" seems rather general, and the question remains whether this refers to the prediction or the experience of reward. In other words, different and imprecise definitions of "reward" are problematic.

Taken together, the application of such a selectivity factor for judging whether reverse inference is possible needs to be done with caution. Given the limited power of reverse inference from single-region brain activations, more sophisticated multivariate methods for interpreting brain imaging data have been at the forefront of analysis techniques. The idea behind these techniques and how consumer neuroscience research related to branding may benefit from those is detailed in the next section of this paper.

What could be done: conclusions and suggestions for future directions

In this last section of the paper we lay out our vision of future consumer neuroscience research and why we think academics and practitioners alike could and should be excited about this new field. Since we have already provided concrete future directions for branding research in our review of what is currently done, we conclude with a broader view on the new directions the field of consumer neuroscience could take to make a substantial contribution to consumer research and the psychology of branding.

The application of neuroscience to consumer psychology, specifically to the psychology of branding, has an interesting potential for at least two reasons. First, it can be viewed as a new methodological tool, as a "magnifying glass" to observe mental processes without asking consumers directly for their thoughts, memories, evaluations, or decision-making strategies, and thus can provide access to otherwise hidden information (Ariely & Berns, 2010; Plassmann et al., in press). Second, neuroscience can be viewed as a source of theory generation, supplementing traditional theories from psychology, marketing, and economics (Plassmann et al., in press). We explain both ideas in the following section.

Neuroscience as a tool

Neuroscience's potential as a tool stems from at least two ways it can contribute to a better understanding of the psychology underlying brands. First, combining advanced statistical models from computer science with neuroscience data makes it possible to predict behavior in a more accurate way than relying on traditional measures such as self-reports. Second, by combining different tools from the neuroscientific tool kit we can establish brain–behavior relationships that are meaningful for understanding the psychology underlying consumer choices.

Predicting consumer choices Empirical studies in consumer neuroscience and neuromarketing employ neuroimaging tools as biomarkers to assess responses to marketing stimuli such as brands, advertisements, packaging and to predict consumer choices.

For example, in a study by Knutson et al. (2007), subjects, while being scanned using fMRI, first saw the product (4 s), then were shown the price of the product (4 s), and finally made their choice (4 s). Subjects reported making their decision consciously only at the very end of each run (i.e., the last 4 s), yet analysis of the fMRI data showed the neural predictors of purchase at earlier time points. Notably, these activation changes could be traced from 8 to 12 s before the decision was made, and before subjects reported having made up their minds. However, the neural predictors did not demonstrate better predictive power than self-reports (pseudo-R^2 was 0.528 when only self-reports were included and changed to 0.533 when neural predictors were added; note that pseudo-R^2 was 0.105 based on neural predictors alone). Taken together, Knutson and colleagues could extract neural predictors at a time when subjects had not made up their minds yet, but these predictors were not fundamentally better at predicting purchase behavior than simply asking the subjects about their preferences.

Another example is a recent study by Berns and Moore (in press) that used a small group of subjects' neural responses to music to predict subsequent market level impact in form of commercial success of the songs (using sales data for a period of three years after the experiment). Interestingly, subjective liking ratings of songs did not correlate with future sales data, but the neural response did (i.e., brain activation within the nucleus accumbens).

New developments in neural pattern classification techniques and multivariate decoding analysis of fMRI data (Haynes & Rees, 2006) are very promising to increase the

predictive power of neuroscientific tools in the years to come. A first study in the context of consumer behavior was done by Tusche, Bode, and Haynes (2010). In their study subjects were presented with images of different cars, and asked either to rate their liking of each car (high-attention group) or perform a visual fixation task (low-attention group). After the task, subjects rated their willingness to buy each car. Crucially, subjects were scanned using fMRI during the task, allowing the researchers to test whether neural activation could predict subsequent car choice. The fMRI data were analyzed using a multivariate analysis approach, in which data were fed into the analysis, showing brain regions between the high- and low-attention groups that predicted subsequent purchase intentions.

The idea behind these techniques is as follows. Whole-brain neuroimaging data acquisition, such as fMRI, generates time series data from thousands of data points across the brain. While standard analyses of neuroimaging data employ large-scale univariate analyses by contrasting different experimental conditions, multivariate pattern classification techniques take advantage of information contained in multiple voxels distributed across space. They allow investigation of whether spatial patterns of brain activation contain stable information about different experimental conditions (e.g., purchase vs. no purchase).

These approaches promise better predictions of decision-making behavior across domains, such as neural, physiological, and behavioral predictors of in-store purchase, unhealthy behaviors, and overspending. We believe that decoding of brain patterns using such sophisticated algorithms will be a turning point for consumer neuroscience research.

Establishing brain–behavior relationships that are meaningful for consumer psychology Another potential way to apply methodologies from neuroscience to consumer behavior is to observe consumers' mental processes in real time. As discussed earlier, this is of particular importance when the underlying processes are difficult to investigate because they are below consumers' awareness or are difficult to verbalize and/or manipulate in a traditional experimental setting or survey. One example was provided by a recent study (Plassmann et al., 2008) that investigated whether marketing actions (i.e., changing the price of a wine) does alter taste processing (i.e., the wine actually tastes better) or cognitive processing because of rationalizing (i.e., the consumer thinks the wine tastes better). It is very difficult for consumers to verbalize whether the price changes how much they think they like the wine or how much they actually like the wine, although this difference is very important from a consumer psychology perspective. The authors could show that changing the price of an identical wine does actually change taste processing and more specifically that part of taste processing that encodes the pleasantness of the taste. This finding provides neuropsychological evidence for a placebo effect of marketing actions on positive experiences similar to placebo effects in the pain domain.

Another approach is to use neuroscientific measures to validate behavioral measures. An example of this approach is a recent study (Dietvorst et al., 2009) that aimed at developing a sales force–specific Theory-of-Mind (ToM) scale in two steps. First, they developed a personality scale measuring salespeople's interpersonal-mentalizing skills, based on questionnaires. Second, they validated the questionnaire-based scale by comparing high- and low-scoring salespeople on the scale when they worked on interpersonal-mentalizing and control tasks while having their brains scanned using fMRI. Interestingly, they found that salespeople who scored high on their sales force-specific ToM scale also showed more activation in brain areas involved in ToM during the interpersonal-mentalizing tasks but not during the control tasks.

It is important to note that the next level of research in this area needs to go beyond merely establishing associations between brain activity and a specific behavior. A review by Kable (2011) showed that 60% to 70% of empirical studies applying neuroscience to behavioral decision-making theories use only one method: fMRI. To establish a deeper understanding of the relationships between neuropsychological processes and behavior that can profoundly advance our understanding of consumer psychology, consumer neuroscientists need to expand the neuroscientific tool kit. The idea behind this is to show that (a) brain mechanisms are necessary for a specific consumer behavior (i.e., when brain activity is interrupted, behavior is impaired) and (b) brain mechanisms are sufficient for a specific consumer behavior (i.e., when brain activity is induced, behavioral effects occur; see Kable, 2011, for a more detailed discussion).

Methods to test necessity include using patients who have a lesion in a specific brain area of interest, such as the vmPFC, and testing their behavior as compared to control populations. For example, it has been shown that focal brain lesions in this area make patients outperform healthy controls in financial performance tasks (Shiv, Loewenstein, & Bechara, 2005). Another way to study necessity is the application of techniques that "virtually lesion" healthy subjects by temporarily interrupting electromagnetic activity (Transcranial Magnetic Stimulation (TMS) or cathodal Transcranial Direct Current Stimulation (TDCS)). A recent study by Camus et al. (2009) showed that the application of inhibitory TMS to subjects' dlPFC decreased subjects' predicted values in an economic auction.

The toolkit to test sufficiency is much more limited and includes primarily a reversed version of transcranial direct current stimulation (anodal TDCS). For example, a study by Fregni et al. (2008) showed that stimulation of the lateral prefrontal cortex reduced craving in smokers.

Beyond testing relationships between brain systems and behavior, another novel and exciting approach is to go one level deeper and test the relationships between specific neurotransmitters and behavior. Recent advances in our understanding of the role of neurotransmitters, and how they relate to processes underlying decision making, may lead to improved understanding of consumer psychology. Few studies, if any, have approached this from a consumer behavior perspective, but insights from studying decision-making on a neurotransmitter-level might serve as a source to generate new research ideas (see Ramsøy & Skov, 2010, for a review). Applying the same

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idea described above, the neuroscientific tool kit allows us to test associations, necessity, and sufficiency of neurotransmitters and specific consumer behavior (see Kable, 2011, for a more detailed discussion).

Specific brain imaging techniques that allow tracking of changes in neurotransmitters (forms of Positron Emission Tomography (PET)) and the study of genetics allow researchers to make associations between neurotransmitters such as dopamine and a specific behavior such as gambling or other impulsive behaviors.

Administration of pharmacological antagonists or depletion of a specific neurotransmitter (e.g., through dietary restrictions) allows researchers to test necessity. For example, a study by Crockett, Clark, Tabibnia, Lieberman, and Robbins (2008) found that serotonin depletion increased rejection of unfair offers in an ultimatum game.

Along those lines, administration of pharmacological agonist or depletion of a specific neurotransmitter allows researchers to test *specificity*. For example, Kosfeld, Heinrichs, Zak, Fischbacher, and Fehr (2005) demonstrated that administration of oxytocin increased trust during economic exchange. Another example is a study by Schweighofer et al. (2008), who tested the effect of serotonin loading and depletion on reward discounting.

Taken together, studies in consumer psychology can benefit from new tools that allow the testing of association, necessity, and sufficiency of neuropsychological processes and consumer behavior. By expanding the toolbox in consumer neuroscience, advances can be made in our understanding of both basic mechanisms and individual differences in consumer decision making.

Neuroscience as basis for theory generation

Although most of the hype around the potential of consumer neuroscience and neuromarketing evolves around using neuroscientific tools, in this review we would like to suggest neuroscientific findings as a novel source of understanding the mechanisms underlying consumer psychology, as pioneered by Wadhwa, Shiv, and Nowlis (2008) and others (e.g., Lee, Amir, & Ariely, 2009; Van Den Bergh, Dewitte, & Warlop, 2008).

Wadhwa and colleagues investigated the effect of product sampling at the point of sale on subsequent consumption behavior (Wadhwa et al., 2008). The authors compared different hypotheses about whether product sampling would increase subsequent consumption behavior, and if so, whether the effects would be specific to the product sampled, to its product category, or to anything perceived as pleasurable. These predictions were based on different theories from psychology, physiology, and neurophysiology of taste and reward. In a series of experiments, the authors found support for the prediction that our general motivation system in the brain is at work when we sample products, leading to an increased subsequent reward-seeking behavior for any other type of reward. Similarly, a study from Van Den Bergh et al. (2008) found impatience in intertemporal choice to be linked to the activation of the general motivation system in the brain.

Another example is a recent study by Ramsøy, Loving, Skov, and Clement (2011) in which women were studied during different phases of their ovarian cycle. It is well known that this cycle has significant effects on female thinking and behavior, including changes in memory, sexual behavior, and mate selection (Jones et al., 2008; Pillsworth, Haselton, & Buss, 2004; Rupp & Wallen, 2007; Vranić & Hromatko, 2008; Zhu et al., 2010). In particular, recent studies have demonstrated changes in consumer behavior, including the increased likelihood of purchasing and wearing sexually suggestive clothing at peak fertility (Durante, Li, & Haselton, 2008; Durante et al., 2010), although Saad and Stenstrom (in press), interestingly, did not find evidence linking menstrual cycle to attitudes towards brand-related information. Little is known about the exact mechanisms underlying such effects and to what extent menstrual cycle affects the processing of different kinds of brands or advertisements. By using eye tracking to assess visual attention, Ramsøy et al. (2011) found that at peak fertility, women tended to show faster and more frequent fixations and longer total viewing time toward sexual elements in ads. Such effects were not at the cost of visual attention toward brand information and did not have an impact on preference or long-term memory scores. Nevertheless, these findings demonstrate how a known biological factor may influence consumer psychology.

These studies are examples of how scholars in consumer psychology can integrate findings and concepts from neuroscience without actually applying neuroscientific methods. This approach is of great potential for developing an interdisciplinary understanding of how consumers make decisions and may provide significant improvements in our understanding of preference formation and decision making. We hope this review will help researchers as a starting point for generating hypotheses based on an interdisciplinary framework to advance existing theories in consumer psychology.

To conclude, in this last section of this critical review, we have pointed out two major new directions in which neuroscience might advance consumer psychology. These new directions extend first findings in the nascent field of consumer neuroscience related to branding and, more important, help to address the issues of previous work reviewed in this paper. We hope this review provides researchers with exciting new perspectives and ideas for their future work in consumer neuroscience to advance our understanding of the psychology of branding.

Acknowledgments

The authors would like to thank Beth Pavlicek, Anupama Deepa Kumar, and the participants of the INSEAD course "Decision-Making and the Human Brain" for their comments on previous versions of this paper. We thank the participants of the tutorial "Decision Neuroscience" at the University of California at San Diego and University of Southern California for their insightful comments on aspects addressed in this paper. We also

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thank the editors and the two anonymous reviewers for their valuable feedback and comments.

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Please cite this article as: Plassmann, H., et al., Branding the brain: A critical review and outlook, *Journal of Consumer Psychology* (2012), doi:10.1016/j.jcps.2011.11.010

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Please cite this article as: Plassmann, H., et al., Branding the brain: A critical review and outlook, *Journal of Consumer Psychology* (2012), doi:10.1016/j.jcps.2011.11.010