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Consumer Neuroscience: Past, Present, and Future

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In this paper we give an overview of the nascent field of consumer neuroscience and discuss when and how it is useful to integrate the "black box" of the consumer's brain into marketing research. To reach this goal we first provide an overview of the research that has laid the foundation of consumer neuroscience, showcasing studies that highlight the concrete promises of applying neuroscience to marketing. Building from this, we discuss the more recent use of brain data to predict market-level consumer behavior, which is a topic that has generated a lot of excitement from academics and practitioners alike. We conclude by providing insights about the newest developments in the field that we think will have an important impact on our understanding of marketing behavior in the future.

Keywords: Marketing; Neuroscience; Consumer Neuroscience

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In recent years, consumer neuroscience research—which applies tools and theories from neuroscience to better understand decision-making and related processes—has generated quite a bit of excitement in marketing and in neighboring disciplines (Ariely & Berns, 2010; Camerer, Loewenstein, & Prelec, 2004; 2005; Plassmann, Ramsøy, & Milosavljevic, 2012; Plassmann, Yoon, Feinberg, & Shiv, 2010; Venkatraman, Clithero, Fitzsimons, & Huettel, 2012). Indeed, a survey of the most productive marketing professors found that consumer neuroscience was considered one of the top five cutting-edge areas in the field (Ladik, 2008).

Building on this, it's useful to consider both *why* and *how* neuroscience techniques such as fMRI hold such potential to improve our understanding of consumer psychology. Studies of decision-making have commonly relied on asking people about their thoughts, observing their behavior directly in various controlled situations, or observing their behavior indirectly using empirical analysis of large data sets. One way that neural and physiological methods can expand this view is by adding distinct new types of data. This includes measuring brain correlates of emotion or affective processing. Such emotions are clearly important in decision-making but are difficult to access with surveys or measures of revealed preferences.

In addition, since many neural (and physiological) methods require no conscious effort, they offer some access to automatic and unconscious processes more generally. As a result, neuroscience can help build process-related models with a more nuanced understanding of how behavior is generated. And because these measures don't have to rely on verbal or linguistic processing, they also help avoid biases in attitudes and behavioral intentions that can be introduced by explicit tests of attribute perceptions, such as surveys (Feldman & Lynch, 1988).

Furthermore, while behavioral methods can offer snapshots of preferences and choices, it can be a challenge to examine how different decision elements develop and change over time.

fMRI and other techniques are able to gather data relating to multiple decision constructs dynamically as a decision or consumption experience unfolds. This also allows the contributions of the same mechanisms to be studied at different stages in the decision process.

The goal of this paper is to offer an overview of the consumer neuroscience field and to discuss when and how it is useful to integrate the "black box" of the consumer's brain into our understanding of consumer behavior. In service of this goal, we first introduce the ways that neural and physiological measures are being applied in this domain. We then provide an overview of the foundational research in consumer neuroscience, showcasing studies that demonstrate the concrete promises of applying neuroscience to consumer psychology. We next focus on a few recent topics that have generated a lot of excitement, such as neural identification of distinct individual differences, or "segments," and better understanding of state-dependent effects in decision-making. We conclude with some thoughts on the trajectory of consumer neuroscience and its importance in improving our understanding of behavior in the marketplace.

The Consumer Neuroscience Toolkit

Empirical studies in consumer neuroscience employ neuroimaging tools as biomarkers to assess responses before, during, and after the decision-making processes. Table 1 gives a brief description of several of these methods and how they have been used in past research (see also Cacioppo, Tassinary, & Berntson, 2007, for a detailed scientific review and Plassmann, Ambler, & Braeutigam, 2007, for a more applied review).

***** INSERT TABLE 1 ABOUT HERE *****

In 2014, we conducted a survey about the state of the field among leading academics (N=59) who currently use neuroscience to investigate marketing questions. The results, depicted in Figure 1, reveal that for these researchers, the most commonly used neuroscience tool is currently fMRI (71%), followed by eye-tracking (57%). While the use of electroencephalography (EEG) is quite widespread in cognitive neuroscience in general, its use by consumer neuroscience academics has been much lower (29%).

***** INSERT FIGURE 1 ABOUT HERE *****

The prevalence of fMRI is an interesting question to consider. After all, it is a complex methodology that requires in-depth training to pursue and is quite costly (scanner rental ranges from US$100 to $800 per hour). These experiments also require participants to lie on their backs and to hold very still during the scans, and it has been argued that this diminishes the ecological, or external, validity of the work. However, a major benefit of fMRI lies in its ability to visualize a tremendous range of information processes underlying consumer behavior. From that perspective, it is one of the most powerful tools available. Better understanding the underlying information processes, or decision mechanisms, is important in understanding *why* a specific behavior arises. Hence it is central for building consumer psychology theories.

The results illustrated in Figure 1 further indicate that researchers appear to approach neuroscientific methods with an aim to combine these tools with traditional behavioral lab experiments (91%). Going forward, they are more likely to seek out additional methods to add to their research, such as applying psychophysiological measures of valence (i.e., facial affective encoding) and arousal (i.e., SCR, heart rate response, and pupil dilation) and measuring or manipulating pharmacological responses to marketing behavior. Taken together, the survey findings suggest that consumer neuroscience researchers regard neuroscientific tools less as substitutes for other types of measurements and more as complements to traditional experimental methods that can add important new insights to further develop marketing theories.

Past: Foundations of Consumer Neuroscience Research

Research categorized in disciplines such as neuroeconomics, decision neuroscience, and consumer neuroscience over the past decade has worked to establish a better understanding of how specific brain circuits contribute to decision-making. One of the most influential early studies that provided a signal for the scientific merit of the field was research that examined the relative preference for two types of "culturally familiar" drinks—namely, Coke and Pepsi (McClure et al. 2004). One of the hallmark findings of this work was that it offered evidence for neural activity in specific areas (the hippocampus and dorsolateral prefrontal cortex) that was correlated with the Coke brand, but not the Pepsi brand. This opened the possibility that marketing actions could be measured in meaningful ways using neural techniques, and that these techniques could generate novel insights.

To some extent, very early consumer neuroscience studies similarly focused on identifying neural correlates of marketing-relevant behavior. Figure 2 illustrates a number of these areas. Indeed, the question of which brain areas encode preferences for products or specific product features, such as brand label, price information, and product category, has received considerable attention.

***** INSERT FIGURE 2 ABOUT HERE *****

For instance, Erk and colleagues investigated preferences for sports cars vs. other types of cars (i.e., limousines, small cars) and found that viewing pictures of the more attractive cars resulted in increased activity in mesolimbic brain areas, such as the nucleus accumbens (NAcc) and ventromedial prefrontal cortex (vmPFC; Erk, Spitzer, Wunderlich, Galley, & Walter, 2002). Deppe and colleagues investigated brand preferences and found that a subject's favorite brand activated significantly more of the vmPFC compared to other brands from the same category that were less liked (Deppe, Schwindt, Kugel, Plassmann, & Kenning, 2005). Knutson and colleagues (2007) investigated which brain areas had activity correlated with judging different elements of a shopping decision, such as the product and/or its price. They found that activity in the NAcc correlated with liking for the product while it was being viewed, while activity in the medial prefrontal cortex was associated with perceptions of monetary value when viewing product and price information. In addition, insula activity increased when participants viewed a price and product pairing they felt was a "rip-off" or bad value, suggesting that it might represent negative emotions associated with price (Knutson, Rick, Wimmer, Prelec, & Loewenstein, 2007). Last, studies by Plassmann and colleagues (2007, 2010) investigated which brain areas coded for a decision-maker's willingness to pay (WTP) using a second price auction mechanism adopted from behavioral economics (a so-called Becker-DeGroot-Marschak auction; Becker, DeGroot, & Marschak, 1964). They found that activity in the vmPFC and the dorsolateral prefrontal cortex (dlPFC) encoded participants' WTP for appetitive and aversive products (Plassmann, O'Doherty, & Rangel, 2007, 2010).

This research—taken together with several other studies that followed, on packaging attractiveness (Reimann, Zaichkowsky, Neuhaus, Bender, & Weber, 2010) and brand preferences (Esch et al., 2012; Schaefer & Rotte, 2007; Schaefer, Berens, Heinze, & Rotte, 2006); for a review see Plassmann et al. (2012)—demonstrated the important role of the mesolimbic system, specifically the vmPFC and striatum/NAcc, for encoding the preferences and values that individuals assign to products or product features. A meta-analysis of such studies involving the neuroscience of decision-making further supported the importance of these areas (Bartra, McGuire, & Kable, 2010).

Present: Moving From Neuroscience to Consumer Neuroscience

These findings provide a necessary first step in understanding how decision elements are coded in the brain, and thus a strong background on how neural methods can be used in future work. However, their direct contributions add more to an understanding of the brain than to our understanding of consumers. While a better understanding of the brain is important from a neuroscientific perspective, it is not the focus of a consumer psychology perspective. We find this distinction reflected in our survey of consumer neuroscience academic researchers, in which "understanding the brain" was rated as the least important direction going forward.

In that same survey, we asked respondents to list the publications they perceived as most influential. Of the top five, three fell into this "first step" category. In particular, 61% of the individuals who answered the question indicated Plassmann, O'Doherty, Shiv, and Rangel's 2008 study on the pricing of wine, 48% listed the McClure et al. 2004 Coke/Pepsi study, and 30% named the Knutson et al. 2007 paper on the neural predictors of purchases described above. Notably, all three of these papers were published in neuroscience journals.

In contrast, the other two papers in the top five were both published in marketing journals (Yoon, Gutchess, Feinberg, & Polk, 2006, 32%, and Berns & Moore, 2012, 20%; discussed below). It is possible to consider this as an indicator of the development of the field. While it was initially important to establish the relevance of neural data for marketing questions, the discipline has progressed to the point where it can offer rigorous study of consumer psychology directly. Indeed, our survey respondents felt that the two top areas of contribution were (1) "dissociating competing theories about information processing underlying decision-making" and (2) "confirming existing theories about mechanisms underlying decision-making." A close third was "identifying new processes in decision-making." In addition, the ability to use neuroscience to predict future behavior was also seen to be an emerging fourth promise. These responses suggest that consumer neuroscience research may best be seen as a powerful complement to existing methodologies, allowing us to strengthen the foundations of consumer psychology as well as offering avenues for new discoveries and advancing its boundaries. In this section, we highlight a number of studies that speak to these four domains.

Contribution 1: Dissociating Competing Theories About Information Processing

Neuroscientific tools can demonstrate dissociations between psychological processes in at least three ways. First, methods such as fMRI can help to dissociate competing hypotheses that cannot be distinguished on a behavioral level (because they result in the same behavior) by showing that they are represented by distinct neural patterns. For example, a common finding in the marketing literature is that marketing actions such as pricing and branding induce expectations about the product's quality that in turn alter choices (Lee, Frederick, & Ariely, 2006) or liking for otherwise identical products during consumption (Allison & Uhl, 1964). Marketing actions can even influence the efficacy or impact of otherwise identical products, such as the ability of a discounted versus a normal-priced energy drink to aid in solving mental puzzles (for review, see Plassmann & Wager, 2014). These effects could be explained by one or more of three possible mechanisms: (1) the existence of reporting biases due to social desirability, (2) motivated reasoning, or (3) that marketing-induced expectations do indeed change how features such as the taste of the product are perceived. Plassmann and colleagues tested these competing theories by scanning participants' brains while they consumed identical wines with different price tags and found that higher prices enhanced the actual taste experience—that is, how the product quality is perceived (Plassmann et al., 2008).

Another example is recent work on preference reversals when choosing between gambles, as opposed to independent bidding on those same gambles (Kim, Seligman, & Kable, 2012). Contingent weighting theory (Tversky, Sattath, & Slovic, 1988) and expression theory (Goldstein & Einhorn, 1987) provide two competing theories about the underlying psychological and computational processes of such preference reversals. However, these two theories cannot be dissociated on a behavioral level because they make the same predictions about behavioral outcomes. To shed light on the information processes taking place "online" while subjects made bids on gambles or chose between them, Kable's group conducted an eye-tracking study (Kim et al., 2012) and an fMRI study (Kim-Viechnicki & Kable, 2014). They found (1) a shift in visual attention from one attribute (probabilities in choices) to another (payoffs in bids) and (2) a change in the influence of these attributes on neural activity in regions associated with valuation. These findings line up best with contingent weighting theory and thus showcase how neurobiological measures can help dissociate competing theories that predict the same behavioral outcomes.

A third example is the investigation of the common assumption in social psychology that hypothetical choices or purchase intentions can be used as good approximations for actual behavior. This assumption is in stark contrast to revealed preference theory in economics, which relies exclusively on real choices as a preference measure. A study by Kang and colleagues (2011) investigated the neural correlates of these two competing preference measures by using fMRI to compare whether hypothetical and real choices recruit similar or distinct neural systems. They found that hypothetical and real choices do recruit overlapping neural systems. However, they also showed that the activation patterns were stronger for real than for hypothetical choices (Kang, Rangel, Camus, & Camerer, 2011).

Last, neuroscientific tools can also test competing formal models of the information processes underlying consumer decision-making (Willemsen & Johnson, 2011). For example, Reutskaja and colleagues (2011) used eye-tracking to compare different models of how consumers conduct dynamic information search over the set of feasible items under conditions of extreme time pressure and choice overload. They found that participants use a stopping rule to terminate the search process that is qualitatively consistent with a hybrid model (informed by neurological data), but not with the satisficing or optimal search models from standard economics (Reutskaja, Nagel, Camerer, & Rangel, 2011).

Contribution 2: Confirming or Refining Existing Theories About Mechanisms Underlying Decision-Making

In the following, we offer several examples of how neuroscientific methods can provide evidence that argues for or against existing psychological theories in marketing, and also how neural data can improve our understanding of the phenomena these theories describe. As a first example, prominent research on brand perception suggests that brands have personalities analogous to human personalities but also have dimensions that are unique to brands (Aaker, 1997). Yoon and colleagues (2006) examined the question of whether brand personalities are indeed perceived in the same way as human ones in an fMRI study comparing neural activity related to judgments in the two categories. They found that judgments about brands and people recruited mostly dissociable neural systems (Yoon et al., 2006). This suggests that despite apparent similarities in the constructs, individuals process information about brands and humans using fundamentally different mechanisms.

Beyond branding, marketers also often use celebrity endorsements to endow a product with the ability to engage consumers socially. However, it remains unclear why these individuals might be more persuasive than other (equally physically attractive) spokespeople. As a first step, a neuroimaging study examining the use of celebrities when they were (or were not) credible experts on a product provided a deeper understanding of the benefits of expertise, controlling for celebrity. When celebrity spokespeople were credible experts, they could create deeper processing and trust and possibly deeper encoding for the target product than non-expert celebrities could (Klucharev, Smidts, & Fernández, 2008). A subsequent study by Stallen et al. (2010) was able to confirm that the benefits of celebrity itself arise from a transfer of positive affect from the individual to the product, arising from (positive) memories and thoughts about the person.

Neuroscience can also support consumer behavior theories related to the question of whether consumers' preferences for an item rely on the awareness of a decision-making context, or the need to make a choice. Research in more traditional psychological disciplines has suggested that individuals form and/or retrieve preferences immediately and automatically (e.g., (Duckworth, Bargh, Garcia, & Chaiken, 2002; Fazio, Sanbonmatsu, Powell, & Kardes, 1986; Zajonc, 1980). That implies that perceptions of an item's value would be similar when it was encountered as part of a choice or when it was encountered in a more neutral or goal-free setting.

A number of recent fMRI papers have addressed this issue, finding direct evidence that the brain encodes preferences in a way that is relevant for choice even when participants are unconcerned with, or unaware of, any need to make a decision (Lebreton, Jorge, Michel, Thirion, & Pessiglione, 2009; Levy & Glimcher, 2011; Smith, Bernheim, Camerer, & Rangel, 2014; Tusche, Bode, & Haynes, 2010). By supporting psychological research on automatic preference formation, this work offers a useful scaffolding for validating and refining other consumer research models.

Last, neural techniques have been applied to questions arising from theories in the information processing literature suggesting the existence of dual systems. In these theories, an emotional system (system 1) pushes one toward quick, intuitive, and suboptimal choices while a second, rational system (system 2) pushes one toward more deliberative and compensatory decisions (Evans, 2003; Kahneman, 2003; Petty & Cacioppo, 1986; Sloman, 1996). However, a neuroimaging investigation found that heuristic, simplifying choices were associated with activation of higher-order cognitive brain systems, while deliberative choices (consistent with expected utility and cumulative prospect theory models) were associated with activation in lower-order emotional brain systems (Venkatraman, Payne, Bettman, Luce, & Huettel, 2009). These results suggest that the standard dual-systems framework may be an oversimplification with the potential to mislead.

Contribution 3: Revealing New Mechanisms Underlying Consumer Decision-Making

The ability of neuroscience methods to visualize and track information processes has tremendous potential for identifying new mechanisms and models in consumer psychology. In this section we outline some of the research demonstrating this benefit.

A central contribution has come from studying the role of visual attention in consumer psychology (Milosavljevic & Cerf, 2008). Visual attention alters the quality of incoming information available for consumer decision-making. As a result, various studies have applied eye-tracking to better understand *how* several aspects of visual attention affect consumer decision-making, including number and length of visual fixations (Krajbich, Armel, & Rangel, 2010; Krajbich, Lu, Camerer, & Rangel, 2012; Krajbich & Rangel, 2011), visual salience of stimuli (Milosavljevic, Navalpakkam, Koch, & Rangel, 2012; Pieters & Wedel, 2004; Towal, Mormann, & Koch, 2013), and subjective meaning of stimuli influenced through branding (Philiastides & Ratcliff, 2013; Pieters, Rosbergen, & Wedel, 1999; Wedel & Pieters, 2000). As a group, these papers highlight the important role that visual attention plays in understanding choices and choice biases. They further demonstrate the ways in which visual attention can be captured using eye-tracking, how visual attention can be manipulated (e.g., length of exposure time, visual saliency of object; Itti, Koch, & Niebur, 1998), and how visual attention as a mechanism can be integrated formally into models of consumer choice using evidence accumulation approaches such as drift diffusion models (Ratcliff, 1980).

A second area that has benefited from the use of neural methods to uncover new mechanisms is the psychology of price. For example, a recent fMRI study by Karmarkar and colleagues examined how early exposure to price information influences how product value is estimated and purchasing decision behavior (Karmarkar, Shiv, & Knutson, 2015). Learning price information before seeing a product, as opposed to afterwards, qualitatively changed the way participants' brains responded to the products they wanted to buy as well as to the products they didn't want. Specifically, differences in patterns of medial prefrontal cortex activity (an area correlated with perceptions of monetary value) suggested that seeing price first caused consumers to shift their decision-making process from a question of "do I like it?" to a question of "is it worth it?" An additional behavioral experiment supported this novel consumer theory by demonstrating that price-first situations increased consideration of products with a clearly defined "worth" or functional value. Putting price first also increased the correlation between stated willingness to pay and purchase decisions, suggesting that this simple shift in information sequence did indeed change the role of estimated (monetary) value and the overall decision process.

Another example, arising from a study by Mazar and colleagues, provides novel insight on a differing dimension of the psychology of price (Mazar, Plassmann, Robataille, & Lindner, 2014). Using fMRI, the authors investigated whether paying a given price is similar to anticipating pain as suggested by behavioral economic theories of the "pain of paying" (Prelec & Loewenstein, 1998). Their brain imaging results suggest that anticipating paying monetary prices and anticipating pain do indeed recruit similar neural systems, but they found an overlap only in higher-order, affective pain processing regions and not other regions of the "pain matrix" in the brain. Building on this result, they conducted two behavioral follow-up studies manipulating affective versus somatosensory pain perception during purchasing decisions through priming and placebo studies and found further evidence for this new mechanism of how monetary payments are perceived. Their results indicate that "pain of paying" is not just a metaphor or a mere analytical process, as standard economic theories suggest; it is indeed a painful experience, albeit a higher-order, affective experience.

Contribution 4: Using Neuroscience to Predict Behavior

The first three promises we discussed can be framed in the context of existing consumer psychology theories. However, neuroscience research has also recently shown a distinct and novel ability to predict consumer behavior directly. Neural methods, particularly from fMRI scans, can track nuances of a person's response to various attributes of a decision, or decision target, as the choice process unfolds, even before a conscious decision is actually made. Taking advantage of this data, several studies have shown that it is possible to predict an individual's future patterns of behavior from his or her own brain activity (e.g., Chua et al., 2011, Demos, Heatherton, & Kelley, 2012; Ersner-Hershfield, Wimmer, & Knutson, 2008; Falk, Berkman, Mann, Harrison, & Lieberman, 2010; Mitchell, Schirmer, Ames, & Gilbert, 2011). Expanding the generalizability of such results, recent findings have shown that it is possible to use neural data from small groups of people to predict the future marketplace behavior of larger populations (see also Knutson & Karmarkar, 2014, for review).

In one of the first such studies, Berns and Moore (2012) scanned people while they were listening to song clips from relatively unknown musicians. Three years later, those same songs had achieved varying levels of popularity, as measured by music sales data. The authors found that the participants' average neural activity in the NAcc during a song was a significant predictor of the song's eventual popularity in the marketplace. Notably, they found that the participants' survey ratings of how much they liked the songs were *not* significant predictors. Prediction of sales success has also been achieved using EEG recordings in an experiment involving individuals watching movie trailers (Boksem et al., 2014). In that work, activity measured by EEG in one group of individuals was significantly correlated with the U.S. box office results for those movies.

Another methodological approach that can be used for prediction is intersubject correlation (ISC). ISC examines the degree of similarity among the neural responses recorded from multiple individuals as they are experiencing the same stimulus. The degree of this correlation has been shown to reflect the fidelity of information transmission, or how consistent and/or similar consumers' level of engagement is with visual media such as movies (e.g., Hasson, Nir, Levy, Fuhrmann, & Malach, 2004; Hasson, Furman, Clark, Dudai, & Davachi, 2008). Recent work measured the ISC of EEG traces from a small group of individuals while they were watching a popular TV program; the researchers were able to use that data to successfully predict the moment-to-moment viewership of that program across the population (Dmochowski et al., 2014). Thus, this technique could offer insights into not only the likely popularity of various media, but also into the kinds of situations or elements that generate the most viewer engagement.

Beyond preferences, neural data can also offer insight into the efficacy of consumer-focused communications in influencing behavior. For example, a "neural focus group" underwent fMRI scanning while watching various anti-smoking campaigns. Their prefrontal cortex activity levels outperformed survey measures in predicting the national success of the campaigns in encouraging "quitting hotline" call volumes (Falk, Berkman, & Lieberman, 2012). On a larger scale, a recent collaborative effort among academics, companies, and the Advertising Research Foundation (ARF) examined responses to ads from multiple brands using a range of traditional and "neuromarketing" methods (Venkatraman et al., 2014). The research tested how well data from these measures on a sample of individuals linked to market-level advertising elasticities. They found that fMRI data was uniquely able to explain variance *beyond* traditional measures such as survey responses. This specific benefit of neural data, present in the majority of the work discussed, is the underlying cause for the contribution this research can make.

Overall, by measuring a distinct set of signals from consumers, neural methods offer novel dimensions of insights into consumer preferences and behavior, and the ability to potentially outperform behavioral measures that have been more commonly used.

Future: New Avenues and Domains for Consumer Research

The work described to this point illustrates several ways neural techniques have proven useful to the field of consumer psychology. These examples also reveal how consumer neuroscience is developing its own integrative field of study, as opposed to a collection of research motivated by either brain science on one side or decision science on the other. Boosted by connections to thriving communities in other disciplines, the pace of this research has been quite rapid, creating a platform to which insights can be added by using more of the neuroscience toolkit (Smidts et al., 2014). In this section, we offer glimpses into a few of these developing domains that push beyond the scaffolding built by behavioral work in consumer psychology to offer new tools and directions that are intrinsically derived from the data offered by neural measures. We can broadly divide them into two areas: (1) better understanding individual differences in consumer behavior and (2) better understanding state-dependent differences in consumer behavior.

Improving Understanding of Individual Differences

A topic of great interest to consumer researchers is the study of individual differences and their impact on decision behavior, and this is a field where neuroscience can add interesting new insights in at least two ways (Venkatraman et al., 2012). First, we can start with known psychological or demographical individual differences of interest and use consumer neuroscience to expand our understanding of them. Second, it is possible to uncover measurable individual differences in the brain and translate those into psychological or socioeconomic individual differences such as personality traits.

Expanding the understanding of known demographics of interest. Individual differences can arise from specific demographic factors such as socioeconomic status or culture. Powerful examples can be found in the study of economic choices made by individuals living under conditions of poverty. By measuring or experimentally altering levels of the hormone cortisol (which is released in response to stress) in various populations around the globe, researchers have been able to identify links between poverty and stress and to causally tie those to changes in risk-taking behavior (Haushofer & Fehr, 2014).

Similarly, cultural neuroscience studies have allowed researchers to better identify links among culture, cognitive and emotional processes, and behavior using neural data as a mediator (e.g., Kitayama & Park, 2010; Kitayama & Uskul, 2011). This field of study can and does discriminate between culturally determined differences at the group level and the individual differences or variations that occur within groups (Na et al., 2010). This suggests a beneficial role for neural data in potentially identifying whether a particular difference, such as representations of the self, should be considered an individual difference or a group difference.

Advanced age is another demographic factor that has been shown to exert distinct influences on consumer psychological processes (Carpenter & Yoon, 2012; Carstensen et al., 2011; Drolet, Schwarz, & Yoon, 2010; Yoon, Cole, & Lee, 2009) and has benefited from new perspectives provided by the use of neuroscientific methods (Halfmann, Hedgcock, & Denburg, 2013; Hedden & Gabrieli, 2004; Mohr, Li, & Heekeren, 2010; Samanez-Larkin, Li, & Ridderinkhof, 2013). The idea behind a “consumer neuroscience of aging” is that the corticalsubcortical brain networks underlying consumer decision-making, and their regulation by neurotransmitters such as dopamine and serotonin, undergo basic biological maturation and senescence as well as plasticity due to the accumulation of experience or changes in motivational goals (Mohr et al., 2010; Samanez-Larkin et al., 2013).

Understanding constraints on brain resources due to aging contributes to better understanding the mechanisms underlying consumer psychology across the life span. For example, several studies have shown that changes in the functioning of the mesolimbic dopamine system as one ages mediate changes in choice behavior during financial decision-making, cognitive control, and intertemporal choice tasks (Cassidy, Hedden, Yoon, & Gutchess, 2014; Denburg et al., 2007; Samanez-Larkin, Kuhnen, Yoo, & Knutson, 2010; Samanez-Larkin et al., 2011; Samanez-Larkin, Robertson, Mikels, Carstensen, & Gotlib, 2009).

Using biological markers to identify/refine individual differences. While the previous section discussed a top-down approach (starting with demographics) to identify, define, and understand individual differences, it is also possible to work from the bottom up. This involves starting with differences in neurobiological markers and using them to better explain certain individual differences. For example, differences in brain structures such as gray matter volume can be linked to individual differences in brain function, personality, and behavior (DeYoung et al., 2010; Newman, Trivedi, Bendlin, Ries, & Johnson, 2007; Peinemann et al., 2005), possibly because they partly reflect the number and size of neurons and the complexity of their synaptic connections. Likewise, individual anatomical differences—for example, within reward-related dopaminergic pathways—have been linked to significant differences in behavioral effects, including variation of personality traits (Depue & Collins, 1999).

A recent consumer neuroscience study provides a new application of these relationships. The authors used an automated structural brain imaging approach in combination with traditional experiments to determine individual differences in expectancy effects of marketing actions such as pricing and branding (Plassmann & Weber, 2015. They found evidence on both brain and behavioral levels that consumers high in reward-seeking, high in need for cognition, and low in somatosensory awareness are more responsive to expectancy effects of marketing actions.

Similarly, a study by Gilaie-Dotan and colleagues (2014) quantified the risk attitudes of consumers using standard economic tasks and also quantified the gray matter cortical volume in several areas across the brain. They found that the gray matter volume of a region in the right posterior parietal cortex was significantly predictive of individual risk attitudes. Specifically, participants with higher gray matter volume in this region exhibited less risk aversion. These correlational results provide first evidence for the existence of a stable biomarker for attitude toward financial risk. Biomarkers such as these could serve as a simple measurement of risk attitudes that could be easily extracted from the wealth of existing medical brain scans, and could potentially offer policy makers and marketers a characteristic distribution of these attitudes across the population.

It is also possible to examine genetic information as such biological markers of individual differences relevant to consumer psychology. Studies on twins have suggested that certain aspects of consumer preferences are heritable and thus likely genetic (e.g., Simonson & Sela, 2011). More directly, neurogenetic studies have identified candidate genes or sequences with ties to decision-related individual differences such as risk-taking or prosocial behavior (see Ebstein, Israel, Chew, Zhong, & Knafo, 2010, for review).

Improving Understanding of "State-Dependent" Differences

Beyond differences among segments of consumers, neuroscience can also reveal variability in one individual's decision-making processes depending on his or her particular (temporary) state. When hungry, under stress, or sleep-deprived, we often make very different choices than when faced with the same options under more neutral physiological conditions. An exciting new approach in studying these differences is the use of pharmacological interventions and measurements.

The idea is that one potential source of state-dependent variability, at a mechanistic level, is the context-sensitive modulation of brain activity by so-called neuromodulators. The term *neuromodulators* includes chemicals that allow neurons to communicate with each other (e.g. neurotransmitters) as well as brain hormones. It covers neurotransmitters such as dopamine (reward processing, motivation, and learning) and serotonin (regulation of mood, appetite, and sleep; social preferences; memory and learning) as well as hormones such as testosterone, cortisol (stress processing), and oxytocin (social preferences and bonding; see Crockett & Fehr, 2014; Kable, 2011).

The levels of neuromodulators in the brain are regulated in response to specific states and events in the environment. So, for example, a highly stressful state might correspond with a higher level of cortisol. Thus, neuromodulators can be thought of as encoding a context, whether it is broadly defined as features of the external environment (e.g., stressors, competitors, potential mates, or riskiness of a decision) or even by internal states (e.g., mood, reproductive status, or hunger levels). Furthermore, these state-dependent varying levels of neuromodulators can then influence information processing in related brain systems (Cooper, Bloom, & Roth, 2003; Crockett & Fehr, 2014; Robbins & Arnsten, 2009). Put another way, neuromodulators both signal the current context and shape neuronal activity to adaptively fit that context.

The functioning of these neurotransmitters and brain hormones can be integrated into consumer psychology research in at least two ways. The first is to establish associations between peripheral levels of a neuromodulator and consumer behavior. In the area of impulsivity and time preferences, a recent study investigated the link between participants' testosterone levels (measured from their saliva) and their preferences for smaller sooner over larger later rewards (Takahashi, Sakaguchi, & Oki, 2006). Interestingly, the study found an inverted-U relationship between delay discounting of gains and salivary testosterone levels, providing some of the first evidence that testosterone might increase the discounting rate for gains over time in distinctly non-impulsive individuals as well as in impulsive individuals. Another example associating neuromodulators with decision-making behavior is a recent study by Chumbley and colleagues (2014). The authors investigated the link between participants' endogenous cortisol levels and behavioral measures of loss and risk aversion. They found that the higher a participant's endogenous cortisol levels were, the lower his or her loss aversion was, but they found no such correlation with risk aversion (Chumbley et al., 2014).

A second avenue for pursuing research with neuromodulators is to manipulate neuromodulator systems, thus providing causal evidence for brain–behavior relationships. It is important to note that direct oral or intravenous administration of neuromodulators is not generally possible except for testosterone and cortisol, because most of these molecules cannot cross the blood–brain barrier. For some neuromodulators, such as oxytocin, a nasal administration, which bypasses this barrier, might be possible. However, the mechanisms by which such intra-nasally administered neuromodulators might enter the brain remain unclear (Chumbley et al., 2014; Nave, Camerer, & McCullough, in press; Walum et al., in press).

Instead, it is possible to directly block or stimulate neuromodulator *receptors*, which are the targets of these biochemicals, with pharmacological agents. These can be antagonists that impair neuromodulator functioning or agonists that increase neuromodulator functioning.

In a study of relevance to consumer neuroscience, Pessiglione and colleagues (2006) administered dopamine antagonists and agonists to impair and increase dopaminergic functioning in the brain during a preference learning task. They found a difference in how learning was guided by rewards depending on whether participants were treated with a dopamine agonist or antagonist (Pessiglione, Seymour, Flandin, Dolan, & Frith, 2006). Their results indicate that decreasing and increasing dopaminergic functioning can account for how consumers learn to improve future decisions.

Another example of a consumer neuroscience study following this approach involved directly administering testosterone and found that consumers' preferences for luxury brands does increase with higher testosterone levels (T levels; Nave, Nadler, Dubois, Camerer, & Plassmann, 2015). For consumers, luxury goods represent social markers that elevate them in the social hierarchy by increasing either status or power. Across two large-scale studies, these findings are the first to show a causal relationship between increased preference for luxury goods and single-dose testosterone administration. In addition, the study also showed that status- but not power-seeking behavior during consumers' product evaluations can be caused by increased T levels.

As these findings illustrate, understanding the pharmacology underlying consumer behavior can generate exciting new avenues for consumer neuroscience to establish causal links between brain and behavior.

Conclusions

In parallel with academic advances, practitioners' interest in applying neurophysiological methods to company-specific market research has also advanced. The number of "neuromarketing" research companies has been growing steadily (Plassmann et al., 2012), and most of the largest marketing research companies currently have neuromarketing divisions or partnerships (e.g., Nielsen, Millward Brown, GfK, TNS). Thus, the impact of using neuroscientific techniques is not limited to the theoretical, but extends into shaping how companies approach, relate to, and design their offerings for consumers.

For many questions in theory or practice it can be helpful to choose the single measurement method that best speaks to the question of interest. For example, to study visual attention, eye-tracking can provide more directly relevant answers than fMRI. However, to provide definitive evidence supporting a particular theory or explanation of behavior, programs of research involving multiple complementary methods offer significant benefits. Combined methods can offer researchers the ability to measure correlation and also to establish the causality of hypothesized neural mechanisms. In particular, the field could benefit significantly by better incorporating approaches that examine whether loss of a particular brain structure causes loss of the hypothesized function. One traditional route to doing so is conducting experiments with populations of patients that have lesions in focal brain areas of interest. Alternatively, for cortical structures, "functional lesions" and other changes in neural activity can be caused temporarily and noninvasively by techniques such as transcranial magnetic stimulation (TMS) or transcranial direct current stimulation (tdcs). Employing these as part of the full portfolio of available methodologies allows us to build a strong scientific pathway with convergent evidence building from neural circuits all the way up to consumer behavior.

Speaking more broadly, the neuroscientific techniques that can be applied to consumer psychology and/or marketing are exciting and extremely powerful. However, they are not independently all-powerful. Rather, they are most useful as a complement to, rather than a substitute for, existing methodology. Specific methods may be well suited to providing insight into one type of question but inappropriate for others. Overall, we believe that consumer neuroscience's strength is in allowing behavioral researchers turn the "black box of the consumer's mind into an aquarium" (Smidts, 2005). As this paper demonstrates, these benefits arise not only from the tools or the data, but from the discipline as a whole, as bringing this field to bear can enrich theorizing in consumer psychology and broaden the impact and scope of marketing.

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Figure 1
Current and predicted usage of consumer neuroscience methodologies by academics in marketing.

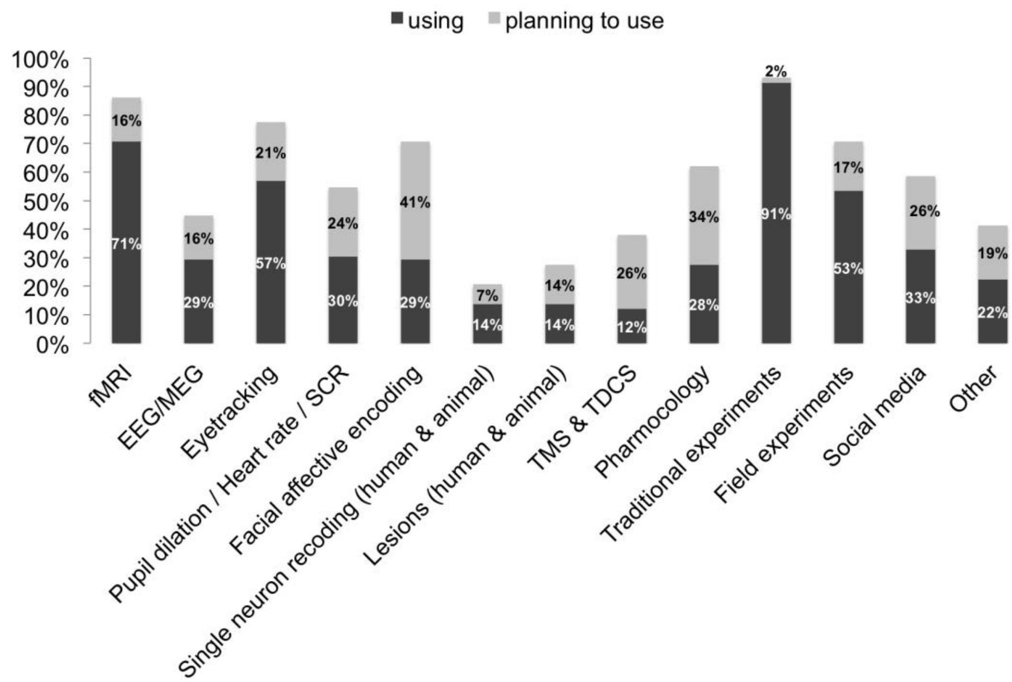

Figure 2
Brain areas involved in consumer decision-making
Source: Adapted from Plassmann et al., 2012

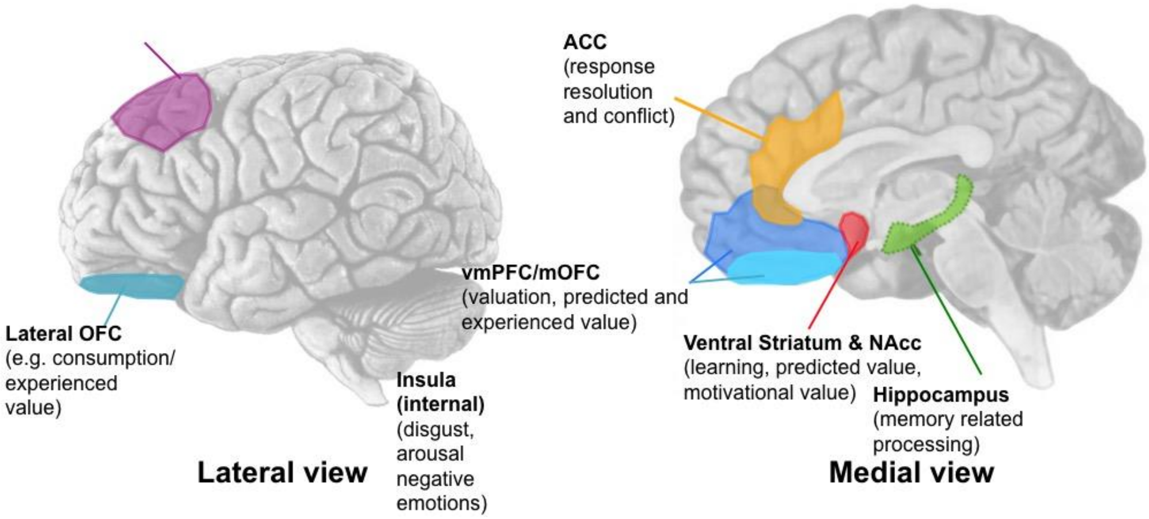

Table 1 : The Consumer Neuroscience Toolkit

Tool	Benefits	Limitations	Typical Use
Electroencephalogram (EEG)*	- can be used to measure signals faster than fMRI - minimal set up, participants able to move around	- spatial localization of brain activity very limited (hard to pinpoint specific brain areas) - does not measure from deep brain structures	- copy testing - instore experience - detecting positive/negative arousal, decision conflict, attention, language processing, some memory effects. - common in neuromarketing research
Functional magnetic resonance imaging (fMRI)	- ability to resolve activity in small structures - differentiates signal from neighboring areas. - whole brain measurement	- physically restrictive, participants lie on their backs in the scanner and can not move around - expensive; equipment intensive	- response to marketing stimuli such as brands and price - localization of neural processing during consumer choices, consumption experiences and value learning - more sophisticated multivariate approaches promise higher predictive power
Transcranial magnetic stimulation (TMS)/TDCS	- can be used to show causality.	- limited to investigating function of surface brain areas. - lowers (or enhances, for tdcs) neural activity generally, can not be used to test "levels" of activity.	- studying causality of specific brain regions for specific mental processes (e.g. preferences, brand choice) by temporarily taking them 'offline'
Eye-Tracking	- offers strong nuanced data on what aspects of an image are grabbing attention, and in what order.	- does not measure inferences, thoughts, or emotions.	- evidence of overt attention - shelf layout - packaging and advertising design - website usability - product placement

Biometrics : Skin Conductance Response (GSR); Heart Rate; Pupil Dilation	- simple, well validated - unobtrusive equipment, allows for more natural interactions with environment.	- can not distinguish valence (e.g. positive vs. negative arousal)	- response to marketing stimuli, in particular commercials - inferences of emotional engagement / arousal during choice processes
Facial Electromyography (fEMG), Facial Affective Recoding	- dynamic tracking of emotional (potentially unconscious) responses to ongoing stimuli/information	- fEMG requires attaching electrodes directly to the face (in a lab)	- valence of response to marketing stimuli, in particular commercials - inferences of emotional valence of information processing during choice
Lesions (patient populations)	- Can establish causality/necessity of a brain area for specific function	- requires access to patient populations - variation in affected areas, and affected functionality across individuals	- choice behavior, particularly in risky/uncertain decision contexts - discriminating conscious vs. unconscious choice elements.
Single Neuron Recording	- insight into how the most basic units of information are coded. - most direct representation of how and when the brain responds to specific stimuli.	- invasive – in humans requires working with medical team on neurosurgery patients - in animals requires extensive training and/or laboratory support	- complementing more abstract models with direct measurement of neural activity - mechanistic data from specific functional areas – can be used to address a range of questions/models
Pharmacology	- allows better understanding of (physiological) state-dependent effects.	- can not measure fast/immediate changes - individual chemicals have multiple effects that can be difficult to isolate, specific effects can be unclear.	- oxytocin – stress, cooperation, social interactions - testosterone – impulsiveness, risk behavior, aggression, social interactions, power - cortisol – stress, conflict, general arousal

* A very similar but more expensive technique not mentioned here is Magnetencephalography (MEG). We do not provide details because of is limited application in consumer research but see (Plassmann, et al., 2007) for more details.