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Advancing consumer neuroscience

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Abstract In the first decade of consumer neuroscience, strong progress has been made in understanding how neuroscience can inform consumer decision making. Here, we sketch the development of this discipline and compare it to that of the adjacent field of neuroeconomics. We describe three new frontiers for ongoing progress at both theoretical and applied levels. First, the field will broaden its boundaries to include genetics and molecular neuroscience, each of which will provide important new insights into individual differences in decision making. Second, recent advances in computational

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methods will improve the accuracy and out-of-sample generalizability of predicting decisions from brain activity. Third, sophisticated meta-analyses will help consumer neuroscientists to synthesize the growing body of knowledge, providing evidence for consistency and specificity of brain activations and their reliability as measurements of consumer behavior.

Keywords Consumer neuroscience · Neuroeconomics · Social neuroscience · Genes · Machine learning · Meta-analysis

1 Consumer neuroscience: the first decade

One of the first papers to discuss the relevance of neuroscience and biology to decision research originated from a workshop on the topic at the Invitational Choice Symposium in 2004 (Shiv et al. 2005). The paper asserted that "knowledge in neuroscience can potentially enrich research on decision-making" (p. 375) and "integrating neuroscience with decision-making offers tremendous potential" (p. 385).

Ten years later, significant progress has been made in decision neuroscience (broadly used to include decision-making research in neuroeconomics, consumer neuroscience, and social neuroscience). For example, we have achieved a sophisticated understanding of how the brain computes the value of choice options and compares these values leading to choice and how context modulates these basic valuation and decision processes (e.g., Levy and Glimcher 2012). The specific subfield of consumer neuroscience, which applies neuroscience insights and techniques to consumer behavior and

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marketing problems, has also prospered. This is evidenced by the increasing numbers of relevant marketing papers using neuroscientific methods, special issues of journals focusing on the topic (e.g., Shiv and Yoon 2012), organization of conferences, and summer schools and symposia. Perhaps most notable is the investments in the field by business schools through faculty hiring and doctoral student training; about 30 business schools have faculty working in this area as per 2013 (electronic supplementary material). The goal of the present paper is to both briefly review the history of consumer neuroscience and highlight new theoretical perspectives and methodological advances.

The field of consumer neuroscience draws heavily on the extant literatures in multiple areas of neuroscience. From neuroeconomics, core examples include studies on the valuation and decision network (Hsu et al. 2005), intertemporal choice (Kable and Glimcher 2007), self-control (Hare et al. 2009), framing (De Martino et al. 2006), and heuristic choice (Venkatraman et al. 2009). From social neuroscience, which uses neuroscientific methods to elucidate the neural basis of social interaction, insights about trust, fairness, and reciprocity (Hsu et al. 2008), mentalizing, empathy, emotion regulation, social exclusion, and pain networks have provided relevant building blocks for approaching consumer behavior (for reviews, see Lieberman 2007; Rilling and Sanfey 2011). Taken together, these advances inform our knowledge both about consumer decision-making processes and how (social) context can affect those processes.

Consumer neuroscience itself covers a broad range of topics. All four elements of the marketing mix—product, price, promotion, and place—have received at least some research attention in the discipline's first decade. Most attention has been given to pricing and products (e.g., Knutson et al. 2007; Plassmann et al. 2008), including branding (for review, see Plassmann et al. 2012). Knutson et al. (2007) demonstrated some of the benefits of using neural methods by having participants engage in a shopping task in the functional MRI (fMRI) scanner. Their work found that adding neural measures to self-report ones led to significantly better predictions of subsequent purchasing decisions.

Plassmann et al. (2008) used fMRI to study whether information that creates expectations about product quality (e.g., price) influences product perceptions via post-consumption rationalizing or via changes in actual taste perceptions. The authors found support for the latter, demonstrating that changing the prices of otherwise identical wines affected brain regions involved in interpreting taste pleasantness while the wines were being sampled. This study provides a prime example of how neuroscience methods can help to tease apart competing theoretical explanations.

Attention to promotion (or advertising) has included work by Klucharev et al. (2008) and Stallen et al. (2010) on the brain mechanisms underlying celebrity endorsements. Packaging and product design were studied by Reimann et al. (2010). In addition, studies have focused on classic consumer research topics such as attraction effects in product choice (Hedgcock and Rao 2009). Notably, the bulk of consumer neuroscience literature has been published in top-tier neuroscience journals rather than marketing journals, making it clear that these marketing phenomena have broad scientific appeal. For example, the Coke/Pepsi study by McClure et al. (2004), arguably the very first published consumer neuroscience article, used neuroimaging to better understand how the brand can affect the experience of consumption.

A unique feature of consumer neuroscience is its direct relevance to practice. Since its early days, industry has followed new developments in the field with great interest. Neuroscientific methods offer hope for solving a core issue for many marketing

researchers: how to reliably measure implicit reactions to marketing stimuli. The marketing research industry has therefore quickly endorsed adopting neuroscience. The number of neuromarketing companies has increased rapidly from an estimated 13 in 2008 to over 60 by 2012 (Levallois et al. 2013). Many of these companies apply biometric methods such as eye tracking, galvanic skin response, and facial coding. Of the direct neural measures, electroencephalogram (EEG), is most popular and with only a few firms employing fMRI thus far. Notably, Neurofocus, a leading neuromarketing company, was acquired by Nielsen in 2011 which may be viewed as a signal that an industry leader in marketing research sees value in the approach.

Ad testing seems by far the most popular area of practical application (as discussed in Ariely and Berns 2010). For example, the Advertising Research Foundation (ARF) has taken an early interest in considering the added value of neuroscience techniques to advertising. In the ARF's NeuroStandards 2.0 initiative, preliminary results from teams of independent academic researchers indicated that while traditional measures are still good predictors of commercial effectiveness, fMRI measures are able to improve those predictions significantly. These results dovetail with recent findings that "neural focus groups" may contain information that can predict out-of-sample behavior and market success even beyond information obtained from conventional marketing methods (Berns and Moore 2012; Falk et al. 2012).

In sum, consumer neuroscience researchers have touched upon a broad range of topics with increasing methodological sophistication. They are also operating in a business context that is very open and eager to learn about these methods and findings. Thus, the field is well positioned to make strong contributions to marketing science in the coming decade. In the next sections, we first discuss the main challenges facing the field and then highlight crucial advances that may promote a greater impact for consumer neuroscience as a discipline.

2 Challenges for consumer neuroscience as a field within marketing

Neuroeconomics provides the closest parallel to consumer neuroscience and may also provide the clearest indication of its future development. Broadly considered, neuroeconomics uses neuroscience to elucidate the mechanisms of decision making, with a particular focus on models and variables often considered within economics (e.g., reward magnitude, probability, temporal delay). Below, we examine several features of the growth of neuroeconomics that could guide research in consumer neuroscience: impact, publishing, and training.

Has neuroeconomics made an impact on our understanding of decision making? While neuroeconomic findings have been of great value for researchers interested in the brain and its functions (Glimcher 2011), others, particularly those motivated by theoretical interests, have argued that this understanding is irrelevant (Gul and Pesendorfer 2008). Between these poles, however, are many researchers who seek to understand the *process* of decision making, including psychological mechanisms that are not directly observable, but may remain agnostic about the added benefit of understanding physiological mechanisms (Camerer et al. 2005). This middle ground—open but skeptical—seems particularly well suited as an audience for consumer neuroscience. Such researchers already appreciate detailed models with psychological factors that shape

individual choices (e.g., Payne et al. 1992). Similarly, neuroscience data might be used to shed light on general processes that underlie decision making. Insight into neural mechanisms is particularly important for understanding why behavior is maladaptive in a broader biological sense (as in addiction or compulsive buying), for distinguishing between competing psychological explanations and for designing more deeply targeted interventions to influence and change behavior.

How has neuroeconomic research been disseminated through the academic literature? A striking feature has been its diversity of publications, spread throughout neuroscience, economics, psychology, business, biology, behavioral sciences, and broad multidisciplinary journals (Levallois et al. 2012). This diversity has both positive and negative effects. Positively, it means that neuroeconomic research both influences and draws upon a number of other fields, which can spark growth as ideas collide, but, more negatively, neuroeconomics lacks the boundaries and integrated literature of fields like marketing, where advances are tracked within a relatively smaller set of journals.

The development of consumer neuroscience will lead to similar challenges in publishing. Researchers face difficult choices in matching interdisciplinary studies to disciplinary journals. Furthermore, disciplinary journals (e.g., within marketing) face challenges in ensuring the rigorous review of papers that apply complex methods from other fields to core questions; those papers will often require larger and more diverse sets of reviews. Devoting special issues to consumer neuroscience is thus very useful to advance the field. Further advancement also partly depends on academic institutions acknowledging this diversity, both in early career training and in mentorship of junior faculty. Those institutions that include interdisciplinary perspectives in hiring committees and tenure packets will gain a comparative advantage in the field. Importantly, research is called for to investigate the career fate of PhDs and junior faculty in neuroeconomics and consumer neuroscience.

Training poses the greatest challenge for any new interdisciplinary enterprise. A natural concern is that such scholars must sacrifice some strength in their core discipline in order to gain a broader skill set. While this concern is surely valid in some cases, we are sanguine about the value of cross-disciplinary training. There are several deep similarities between the analytic methods of different disciplines allowing analogous modeling approaches o be applied. For example, regression and time series analyses lie at the core of both econometrics and functional neuroimaging. Moreover, marketing science itself has long welcomed cross-disciplinary training, as individuals with backgrounds in statistics, psychology, and computer science make important contributions to current scholarship. Accordingly, we see the introduction of neuroscience as not an attempt to replace disciplinary training, but as a way of complementing such training by incorporating insights from a new domain.

In sum, an initial focus of consumer neuroscience on core decision-making topics (as did neuroeconomics) may yield a critical mass of high-quality work with a maximal impact within marketing. Once established, this foundation could be bolstered and elaborated upon. By first emphasizing the use of neuroscience as a tool for understanding behavior, researchers might be more rapidly and systematically trained in methods common to consumer neuroscience and consumer science. Next, we discuss three new frontiers that can focus the field on key questions.

3 New frontier: genetics and molecular neuroscience

Here, we look forward to the increasingly feasible prospect of studying the biological basis of consumer choice behavior at the molecular level. We discuss two fundamental questions: Is it feasible for current methods and techniques to shed light on the genetic and molecular mechanisms underlying consumer choice behavior? Can such knowledge be translated into practical value for consumer researchers?

Genes and human behavior have long had a tempestuous relationship in both science and society (Plomin 1990). There is now increasing consensus that choice behavior, like all complex biological traits, is the result of interactions between genetic, environmental, and developmental/epigenetic processes (see Fig. 1).

Early studies at the interface of genetics and decision making clearly link genetic differences to choice behavior as shown in financial risk taking (Cesarini et al. 2008) and prosocial behavior and empathy (Knafo and Plomin 2006). The heritability of these traits typically ranges from 0.2 to 0.5, which is consistent with phenotypes that are moderately heritable (Plomin 1990). More recently, molecular studies have shed light on the specific proximal mechanisms mediating these effects, robustly demonstrating the role of specific molecular pathways, especially the dopaminergic system, in representing rewarding properties of stimuli (O'Connell and Hofmann 2012).

Much like the synthesis of neuroscience and the study of economic decision making more than a decade ago, we are only now beginning to understand the molecular mechanisms underlying consumer choice processes. Recent work has started to even systematically investigate gene-culture interactions on brain and behavior (Kitayama and Uskul 2011). Genetic and molecular differences provide a novel set of measures for consumer researchers and may yield additional insights that are not contained within existing segmentation and targeting methods during product development processes, akin to notions of "personalized medicine" where medical treatments are tailored to individual patients according to their profiles. The practical application of such techniques, however, will depend largely upon data access as well as ethical concerns about the use of sensitive genetic data. As we are witnessing in the US health-care industry, these are, however, surmountable obstacles where there exist clear benefits to consumers and appropriate guidance regarding data access (Jensen et al. 2012).

In addition, understanding the genetic and molecular basis of choice behavior can shed light on how preferences are formed. Consumer researchers have long posited that

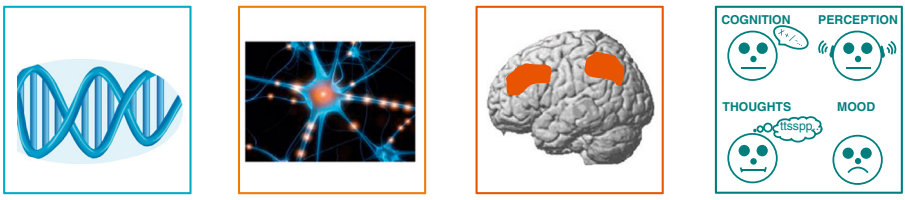

Fig. 1 From genes to behavior. Genes do not specify behavior directly but rather encode molecular products that build and govern the functioning of the brain through which behavior is expressed. Such traits may be proximate, such as cognitive functions and behavior intimately tied to survival and reproduction, or distal, such as wealth (adapted from Rasetti and Weinberger 2011)

preferences are "constructed" rather than "innate." However, even constructed preferences do not arise de novo but are influenced by biological factors including genes that encode elements of brain structure and function (Simonson and Sela 2011). Future research may therefore shed light on how the preference construction process is influenced and specified at different biological levels.

Perhaps most importantly, molecular biology can be used to enhance a collection of experimental paradigms and theoretical frameworks in consumer research that have great relevance for important policy and scientific questions. There is a growing interest, for example, in obesity and dietary compliance, as well as long-standing interests in addiction that overlap both fields. One of the challenges in these areas is the fact that phenotypes such as obesity and addiction arise from a complex interaction between environmental context, biological factors, and behaviors (Ebstein et al. 2012). That is, genes promote obesity through their influence on a set of consumption behaviors (Bell et al. 2005). Consumer researchers therefore have distinct advantages in conceptualizing the decision processes that may lead to overconsumption, for example, individual differences in self-control or emotion regulation. These models could be used in tandem with molecular biology findings in ways that place consumer neuroscience at the forefront of research on such problems.

4 New frontier: computational methods for relating brain to behavior

The rise of neuroimaging tools with enhanced spatial resolution on the order of millimeters and temporal resolution on the order of seconds in the 1990s sparked research that not only illuminated neural components of choice (e.g., value, risk) but also neural *predictors* of choice. In the short span of a decade, scientists were able to trace a path through the brain from sensory input to behavioral output. Accordingly, the key question in consumer neuroscience has now shifted from "can brain activity predict choice?" to "how well can brain activity predict choice?"

More recent technical advances in consumer neuroscience have occurred in at least three fronts. First, continuing innovations in scanner strength, speed, and stability provide steady improvements in spatial and temporal resolution. A second front involves advances in modeling of behavior and linking key components of these models to underlying neural function to elucidate processes that generate choice. This has led to a proliferation of model-based studies of neural function (Montague et al. 2006) that typically apply choice models to behavioral and neural measures to resolve choice dynamics within individuals or across individuals. For instance, researchers have used these measures to identify and characterize individual differences (e.g., Bhatt et al. 2010). Thus, these neurobehavioral models may eventually inform more specific and nuanced accounts of economic decision making in the context of consumer behavior (e.g., segmentation).

The third front involves advances in analysis and inference stemming from applying new techniques that have been developed for analyzing massive amounts of multivariate data (e.g., machine learning) to neuroimaging data (Pereira et al. 2009). For instance, algorithms can identify multivariate patterns of brain activity that correlate with future behavior. The generality and robustness of multivariate solutions can be established both within and across subjects with techniques such as cross-validation.

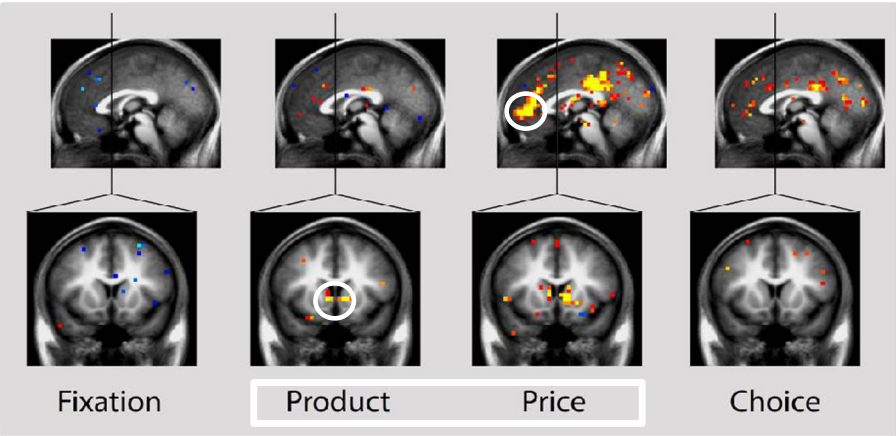

Fig. 2 Whole brain classifier (GraphNet) optimally selects brain features in space and time which predict choices to purchase or not to purchase products in the Knutson et al. (2007) SHOP task (tenfold cross-validation=69.1±2.2 %; adapted from Grosenick et al. 2009). Note the selection of ventral striatal features during product display and medial prefrontal and posterior cingulate features during price display (*circled*), in contrast to the relative absence of selected features during fixation and choice periods

These multivariate methods thus can substantially improve predictions of choice relative to traditional univariate methods (e.g., Grosenick et al. 2013). In addition, such solutions can provide more qualitatively nuanced findings; multivariate solutions applied to a staged choice can reveal both where and when neural activity contributes to eventual choice (Fig. 2; e.g., ventral striatum during product presentation, medial prefrontal cortex during price presentation). By identifying distinct neural components of a decision process, existing theory can be refined and improved. The open availability of these research tools should promote quantifiable and replicable improvements in the future. We therefore anticipate great promise for the use of multivariate techniques in marketing practice.

5 New frontier: meta-analytic synthesis of neuroimaging findings

To date, the workhorse technique in consumer neuroscience has been neuroimaging (fMRI). In many cases, dozens of neuroimaging studies now bear on a given question. A new frontier involves developing and implementing meta-analytic approaches to synthesize this increasingly vast literature. Since the power in any one neuroimaging study tends to be low, meta-analyses can clarify findings of individual studies and can also answer novel questions that individual studies have not yet posed. Meta-analytic techniques can be used to address not only the reliability of activations across studies but also their specificity. Specificity is crucial because it speaks to the validity of reverse inference—the ability to conclude that a person was in a specific psychological state given the observed activation in a specific brain region (Poldrack 2006).

One approach has been to apply meta-analytic techniques to databases constructed by researchers to address specific questions. A recent study (Bartra et al. 2013) used this approach to test the consistency of evidence for a "valuation system," as proposed in previous reviews of the consumer neuroscience literature (Yoon et al. 2012). The

authors analyzed 206 studies that reported activations for higher valued items compared to lower valued items at all stages of the decision-making process (decision, outcome anticipation, outcome receipt). Two regions—ventromedial prefrontal cortex (vmPFC) and ventral striatum (VS)—consistently showed higher activity for more valuable items. These regions reliably showed this pattern both at the time of a decision and at the time of outcome receipt as well as both for primary and monetary rewards.

Meta-analysis can also be applied to publicly available databases that are constructed using automated text-mining techniques (see neurosynth.org; Yarkoni et al. 2011). A great advantage of this approach is its speed and ease of use. Two recent reviews demonstrate the power of this approach. Carter and Huettel (2013) use a series of Neurosynth meta-analyses to localize a part of the temporoparietal junction that is specific to social processing and show how the response properties of nearby regions suggest the specific types of cognitive processes that might be occurring in this region during social processing. Knutson and Karmarkar (2014) use a series of Neurosynth analyses to distinguish appetitive from consummatory activity in valuation circuitry.

The emergence of meta-analytic studies illustrates an important point that might escape the casual reader of the consumer neuroscience literature: there are now enough relevant neuroimaging studies to do high-powered meta-analyses on important questions in the field. One way these meta-analyses advance consumer neuroscience is by demonstrating the consistency of brain activations that provides the necessary foundation for testing more advanced hypotheses. For example, the ventromedial prefrontal and ventral striatal regions that have been repeatedly associated with valuation have served as primary targets for studies using neuroimaging data for prediction of consumer behavior (Berns and Moore 2012; Falk et al. 2012; Knutson et al. 2007). Beyond consistency, meta-analyses are also advancing the field by answering questions—especially about specificity—that individual experimental studies have not yet been able to address.

6 Conclusion

The first decade of consumer neuroscience provided basic building blocks for understanding consumer choice and behavior. It is no longer a question whether neuroscience and neuroscientific methods have anything useful to offer to consumer behavior; there is a growing body of knowledge on how human decision making is shaped by physiological factors. In this paper, we outlined new perspectives and new methods that will likely come to the fore in the near future. Overall, we feel that the field would benefit from a focused and programmatic approach similar to that adopted by neuroeconomics. Given the quick adoption of neuroscientific methods by marketing practitioners, challenges to consumer neuroscientists involve informing practitioners about the use of proper models and methods as well as encouraging them to engage in evidence-based neuromarketing. To the benefit of the general public, we expect consumer neuroscience insights to help in developing more effective interventions and improved support of consumer decision making and to identify vulnerabilities that may inform policies for consumer protection. Because of the fundamental importance of choice behavior, we expect progress in

consumer neuroscience shortly to inform and enlighten not only academic researchers but also practitioners and the general public.

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