Functional Magnetic Resonance Imaging in Consumer Research: A Review and Application

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ABSTRACT

Although the field of psychology is undergoing an immense shift toward the use of functional magnetic resonance imaging (fMRI), the application of this methodology to consumer research is relatively new. To assist consumer researchers in understanding fMRI, this paper elaborates on the findings of prior fMRI research related to consumer behavior and highlights the features that make fMRI an attractive method for consumer and marketing research. The authors discuss advantages and limitations and illustrate the proposed procedures with an applied study, which investigates loss aversion when buying and selling a common product. Results reveal a significantly stronger activation in the amygdala while consumers estimate selling prices versus buying prices, suggesting that loss aversion is associated with the processing of negative emotion.

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Advances in brain imaging allow researchers to enhance knowledge about how individuals process different stimuli and reach decisions. Recently developed forms of neuroimaging, such as functional magnetic resonance imaging (fMRI), permit precise measurement and localization of brain activation. This enriches research by providing evidence of phenomena occurring within the individual's mind, which otherwise are difficult to capture.

Using brain imaging offers four distinct methodological advantages: (1) fMRI permits interpretation of psychological processes in the brain as they are taking place; (2) fMRI enables measurement of nonconscious conditions and processes; (3) fMRI allows localization and differentiation of constructs that subjectively may seem similar but which are actually processed differently; and (4) fMRI makes feasible measurement of the simultaneous activation of two antithetical conditions and processes.

The following example illustrates these four advantages. A consumer being asked for the experienced risk of his or her last stock market investment on a questionnaire tends to think about this question rather than to actually "re-feel" or "re-experience" the situation (Wood & Zaichkowsky, 2004). Since financial risk-taking has a strong emotional component (Kuhnen & Knutson, 2005; Loewenstein et al., 2001), thinking about a past investment experience—i.e., engaging cognitive processes about it—may distort actual emotional aspects. Aimed at capturing such emotional aspects, the specific design of neuroimaging experiments allows the assessment of financial risk-taking and its neural correlates at the time it actually takes place. Further, fMRI permits the differentiation of mechanisms underlying risk aversion and risk seeking, which past research conceptually regards as being opposite poles on a continuum (Weber & Milliman, 1997). Recent neuroimaging research shows that individuals process risk seeking and risk aversion in different brain areas and that these areas can be activated simultaneously, raising the question of whether risk aversion and risk seeking are indeed distinct dimensions (Kuhnen & Knutson, 2005).

These four methodological advantages allow neuroimaging methods to generate a more fundamental conceptualization and understanding of underlying conditions and processes as well as a refinement of existing conceptualizations of various phenomena. For example, brain images taken from a consumer making a buying decision not only reveal the motor areas that are active when the consumer presses a button to choose the presented product. The images also reveal other relevant areas such as the occipital cortex, which is responsible for vision, or areas of the brain's reward center. Thus, neuroimaging may offer deeper insight into both the cognitive *and* emotional processes and provide a broader assessment, leading to a more thorough conceptualization of the phenomenon of interest.

The number of applications of neuroscientific methods in the domain of psychology has increased significantly within the last decade. Today, there is no question that the integration of neuroscience into psychological research is vital in determining understanding of all behavior (Zillmer, 2004). In contrast to their high prevalence within psychology, neuroimaging applications in the field of consumer research have so far remained scarce. Recently, *consumer neuroscience*—or *neuromarketing*—has sparked growing interest, both in the popular press (Helliker, 2006; Park, 2007) and as a focal point of academic business research (Shiv, 2007; Smidts, 2002; Yoon et al., 2006). Further, regular round table meetings at conferences of the Association of Consumer Research laid out roadmaps for further investigation. Academic societies and publications such as the Association

for NeuroPsychoEconomics and the American Psychological Association's *Journal of Neuroscience, Psychology, and Economics* have been founded and foster research in this area. Consumer neuroscience studies on neural conditions and processes to date have predominantly analyzed the effects of advertising, products, pricing, branding, sales, and consumer choice (a more detailed review of the different research areas in consumer neuroscience is provided later in this article).

However, the use of neuroscientific methods is still far from pervasive among consumer behavior scholars. A possible diffusion barrier may be a low level of understanding of neuroscientific methods in consumer research, making proper evaluation of the usefulness of those methods difficult (Lee, Broderick, & Chamberlain, 2007). The purpose of this article is to provide insights into the method of fMRI, currently the most widely used neuroimaging technique in affective, cognitive, and social neuroscience (D'Ardenne et al., 2008; Thompson & Zola, 2003). The paper aims to enable a broader audience of marketing and consumer researchers to reach an informed choice as to whether fMRI is appropriate for their specific research applications. Clearly, this task is challenging, as some readers may hold advanced knowledge while others may be novices in the field of fMRI. To meet this challenge, this paper uses language accessible to a wider target group of consumer researchers and provides an application of a buying–selling experiment. Whereas the results of this study have been previously published (Weber et al., 2007), this article presents its methods to illustrate the fMRI procedures proposed here.

ADVANTAGES OF fMRI IN CONSUMER RESEARCH

While consumer neuroscience is a young research discipline, the relationship between consumer behavior and neuroscience was recognized in the late 1970s (Kroeber-Riel, 1979). Recently, consumer neuroscience, with its related research stream of neuroeconomics, has developed into its own field. Like neuroeconomics—where "neuroscience findings raise questions about the usefulness of some of the most common constructs that economists commonly use, such as risk aversion, time preference, and altruism" (Camerer, Loewenstein, & Prelec, 2005, pp. 31–32)—consumer neuroscience draws from several disciplines. Social sciences such as psychology, sociology, and anthropology all contribute to the prediction and explanation of the measured phenomena (Braeutigam, 2005; Sanfey et al., 2006).

Marketing provides theoretical and managerial research problems, neuroscience sheds light on the anatomy of the human brain and its functions, and neuroscientific methods support the localization and differentiation of the inner conditions and processes. On the basis of these different disciplines, consumer neuroscience can be formally defined as the study of the neural conditions and processes that underlie consumption, their psychological meaning, and their behavioral consequences.

Most research in consumer neuroscience has focused on certain psychological constructs related to preferences, judgments, and choices. Concepts are operationalized in the form of visible or gustatory stimuli, and are presented during experiments. Researchers then measure the activity in the human nervous system in reaction to the presented stimuli. In doing so, they draw from a broad spectrum of neuroscientific methods, which include the measurement of psychophysiological parameters (e.g., blood pressure, pulse, development of perspiration, expansion of pupils, or eye movement) and imaging techniques.

The underlying rationale for the use of imaging methods is to compare the brain's activation during a specific task to its activation during a control task. Differences in the generated images allow investigators to draw conclusions about diverse activations of different brain areas associated with the specific task. While several different imaging techniques exist—including electroencephalography (EEG) and magnetoencephalography (MEG), which measure changes in electrical brain current, and positron emission tomography (PET), which measures emissions from radioactive chemicals in blood—fMRI has become the most frequently used imaging method (D'Ardenne et al., 2008; Thompson & Zola, 2003). Thus, this paper concentrates on fMRI and its usefulness for consumer research. However, other techniques often complement fMRI studies. For example, while fMRI provides a good spatial resolution of the brain, EEG offers advantages in terms of temporal resolution, which describes the time between actual activation in the brain and measurement (Rossiter et al., 2001). Therefore, fMRI is best viewed in the context of other methods and measures to provide a balanced picture of this methodology.

At least four features make fMRI an attractive candidate for the purpose of better understanding conditions and processes related to consumer behavior. First, fMRI permits the interpretation of psychological processes in the brain as they take place during information processing. Thus, investigators can measure underlying processes *while* they occur. This concurrent measurement is not feasible, for instance, with self-reports, which most often require respondents to make judgments about inner conditions *ex post* (Stayman & Aaker, 1993). Accordingly, fMRI may attenuate problems associated with recall bias (Sudman & Bradburn, 1973).

Second, fMRI may enable the measurement of nonconscious conditions and processes (i.e., conditions and processes below some subjective threshold of awareness). Since fMRI does not rely on verbal or written information from the respondent, it circumnavigates cognitive biases. In contrast, traditional self-assessment measures commonly used in consumer research rely on the ability and willingness of the respondents to accurately report their attitudes or prior behaviors (Lee, Broderick, & Chamberlain, 2007; Petty & Cacioppo, 1983). However, nonconscious conditions and processes can significantly influence the processing of a stimulus (Derbaix & Abeele, 1985; Janiszewski, 1988). Given substantial evidence that nonconscious phenomena affect much information processing (e.g., Adolphs et al., 2005; Chartrand et al., 2008; Fitzsimons et al., 2002), fMRI may hold significant promise for improving the understanding of many aspects of consumer behavior.

Moreover, implicit psychological measures aimed at picking up nonconscious processes, such as the implicit association test, have been criticized as being arbitrary (Blanton & Jaccard, 2006). Unlike these implicit measures, fMRI makes brain activation visible, and therefore may offer a basis for further differentiating conscious and nonconscious conditions and processes. For example, researchers could potentially distinguish between specific conscious thoughts that arise in the frontal lobe of the cortex and nonconscious, subtle emotions that arise subcortically. Differentiating these two processes depends on the experimenter's ability to link specific stimuli to one or the other process. Additionally, brain activations could be compared to self-reports collected after brain scans to shed more light on the particular experience the participant had during the scan.

Third, fMRI makes possible the localizing and differentiating of constructs that individuals may subjectively perceive as similar, but which they actually process differently. For example, one fMRI study of people's perception of personality of brands and faces demonstrated that the areas of processing differ between brand and person judgments—a result that brought into question the way marketing has applied the concept of brand personality (Yoon et al., 2006). Thus, fMRI can serve to confirm the admissibility of drawing analogies between the processing of different stimuli.

Fourth, fMRI makes feasible the measurement of simultaneous activation of two antithetical conditions and processes. Whereas the simultaneous appearance of two antithetical processes, such as risk aversion and risk seeking (Kuhnen & Knutson, 2005) or intrinsic and extrinsic motivation (Emonds et al., 2011), would create validity problems within a questionnaire-based survey, employing fMRI allows the researcher to cleanly isolate those two processes (Monterosso & Luo, 2010). Future investigations with fMRI may shed new light on other antithetical constructs relevant to the marketing discipline, such as trust and distrust (Lewicki, McAllister, & Bies, 1998).

LIMITATIONS OF fMRI IN CONSUMER RESEARCH

Although fMRI offers great promise for consumer research, it is subject to several limitations. The first limitation may occur in using neuroimaging results for reverse inference from brain activation to brain function. Traditionally, researchers use fMRI as a measure of brain activity while a subject is performing a specific task. These data then allow inferences of information about the role of a specific brain region in brain function (Poldrack, 2006). However, research increasingly uses fMRI data to infer in the opposite direction by concluding that a specific brain function is based on the activation of an identified brain area. Researchers should use caution in making reverse inferences, especially when theory-based confidence in the engagement of function in a specific brain area is low.

For example, Aron et al. (2007) criticized a neuroimaging study on political candidates by Iacoboni et al. (2007) because activity in the amygdala in reaction to viewing one candidate was said to indicate anxiety, while activity in the anterior cingulate cortex was said to reflect mixed emotions. Aron et al. (2007) argued that it is hardly possible to infer a specific function such as anxiety from the activation of a specific brain area such as the amygdala because the amygdala also engages in other functions such as learning (Paton et al., 2006).

Researchers must balance the use of prior findings and existing theory regarding a specific brain area and its function on the one hand and the urge to explore potentially new areas on the other hand. Importantly, the interpretation of findings should reflect neuroscientific literature, to enable the interpretation of the observed activations and to explain implications for marketing theory and practice. Reverse inference can also be improved by carefully linking the task that subjects performed with the neuroimaging data and reporting all relevant task characteristics (Christoff & Owen, 2006).

A second limitation is that neuroimaging tasks have a restricted level of complexity and may appear to be simpler than other behavioral experiments or surveys. Since stimuli must be repeated to gain enough data per subject, the number of manipulations is limited, lowering task complexity and, therefore,

focusing the research project on more essential questions. For example, someone interested in the neural correlates of brand extensions of cosmetic products might select five different cosmetic brands and then five possible extensions per brand, resulting in 25 brand presentations. However, these 25 presentations would have to be repeated to gain a substantial data set. With only four repetitions, the task will consist of 100 trials over the course of the entire experiment, reaching the maximum in terms of task length.

Third, another potential limitation of fMRI is its temporal resolution. Despite the superiority of the spatial resolution of fMRI to other neuroimaging methods such as EEG and PET as well as to brain lesion studies, the temporal resolution properties of fMRI are challenging. Specifically, fMRI can distinguish between stimuli a subject encounters as little as one second apart from each other, yet some marketing stimuli, such as parts of television commercials or movie trailers, may elicit responses at an even shorter time interval. A possible solution to this problem is to carefully create "digestible" experimental stimuli. For example, a researcher interested in the differential activation of positive and negative advertising stimuli would design the experiment so that the subject encounters positive and negative stimuli separately for one to two seconds each, thus enabling the researcher to differentiate between the valance of these stimuli in the brain at different time points. If stimuli are not changeable (as in the case of a prerecorded television spot), the researcher could combine fMRI with a second neuroimaging method such as EEG. Here, the good temporal properties of EEG (i.e., down to the millisecond level) may inform the researcher whether one brain area is activated before the other in the range of milliseconds. In fMRI, these brain areas will appear in the same brain image. With EEG data at hand, the researcher could then go back and see whether a temporal difference occurred for this particular time interval.

UNDERSTANDING fMRI METHODOLOGY

Since most neuroscientific studies assume some prior knowledge of the underlying methodology, a synopsis of important terms and techniques can aid in understanding and appreciating the implications of those studies. This section provides a brief methodological background on some of the basic concepts of fMRI (Buxton, 2002; Huettel, Song, & McCarthy, 2004; Reimann & Weber, 2010).

Magnetic Fields and Pulse Sequences

fMRI uses strong magnetic fields to create images of the brain. The main magnetic field in fMRI scanners is static (i.e., it does not change over time) and is expressed in units of tesla. While typical fMRI scanners create static magnetic fields that are 1.5 to 3.0 tesla in strength, experimental scanners generate stronger fields of 7.0 tesla or more. Strong magnetic fields are necessary to stimulate the most abundant building block in the human body, which is water. Outside the fMRI scanner, the hydrogen atoms in the participant's body spin in random directions. Once the participant is inside the fMRI scanner's static magnetic field, the hydrogen atoms are pulled in a uniform direction.

To create an image of the brain, the fMRI scanner sends *radiofrequency* (RF) *pulses* into the static magnetic field in which the participant is placed. The

radiofrequency pulse pushes the hydrogen atoms away from their uniform direction. Subsequent to the radiofrequency pulse, the atoms spin back to the uniform direction. The measurement of these effects is the basis for distinguishing between tissue types and, thus, for creating brain images. To generate and receive a radiofrequency pulse, a so-called *radiofrequency coil* is needed. This coil usually is placed directly around the participant's head.

A series of identical pulses is referred to as a *pulse sequence*. Two important aspects in the design of a pulse sequence are the *repetition time* (TR) and the *echo time* (TE). The repetition time is the time interval between identical radiofrequency pulses exciting the brain. Typical repetition times are between 1.5 and 3 sec. The echo time is the time interval between an excitation pulse sequence and data acquisition. Depending on the brain area of interest and type of scanner, the echo time is usually between 25 and 60 ms.

Although TR and TE are typically preset at most imaging centers, one must recognize what governs the choice of TR and TE. While a longer TR provides a higher signal-to-noise ratio in the brain images (i.e., the images are less susceptible to inhomogeneities in the magnetic field) and higher statistical power in discriminating between more and less activated brain areas, a longer TR will also increase the overall time of the experiment, which may lead to fatigue. Besides TR, TE is another important variable because it affects the quality of the image. Generally, fMRI images can have different contrasts, ranging from lighter to darker depending on the fluid content of the tissue (for a review of contrasts including T1, T2, and T2*, see Huettel, Song, & McCarthy, 2004).

In consumer studies using fMRI, the so-called T2* contrast (also called T2* weighting) is most often the contrast of choice. A subject's performance of a task causes an increase in the value of T2* in the brain region that is engaged in the task. This increase can be detected in T2*-weighted images. Moreover, the amount of T2* weighting that appears in a brain image depends on the TE. For a given value of T2*, brain images with a value of TE equal to T2* will be best at detecting any change in T2*. Consequently, an important step is to find the value of TE that will give the best detection of even the smallest changes in T2* in the region of interest. As a rule of thumb for setting an appropriate TE value, at 35 ms TE the BOLD T2* effect is at 80% of its maximum (Van Gelderen et al., 1995) (the BOLD effect is described in the following section).

Because of possible variations in magnetization and pulse sequences, consumer research using fMRI should report the manufacturer and model of the magnetic resonance tomography, its magnetic field strength (in tesla), and the pulse sequence type used (i.e., gradient/spin echo, EPI/spiral). Additionally, reports should specify TR (in seconds) and TE (in milliseconds).

Blood Oxygenation

The *blood oxygen level dependent* (BOLD) signal—also called the *hemodynamic response function* (HRF)—is one of the key effects observed with fMRI. By sending out radiofrequency pulse sequences and listening for echoes, fMRI is able to differentiate between oxygenated blood, which increases in active brain areas, and deoxygenated blood. At a magnetic field strength of 1.5 tesla or more, oxygenated blood is significantly less magnetic than deoxygenated blood. When a

neural activity triggers a change in the BOLD signal, more blood with attached oxygen has reached the brain area of interest. This change is called the *hemodynamic response* (HDR). Although the BOLD signal is strongly correlated with brain activity (Logothetis & Wandell, 2004), the BOLD signal is only an indirect measure of neural activity, and researchers using this signal must be cautious to avoid false implications.

Comparing brain areas with and without hemodynamic response allows identification of a functional contrast between active and non-active brain areas. Changes in the brain are discernible across specific locations (i.e., *spatial resolution*) as well as across time (i.e., *temporal resolution*). The smallest element in spatial resolution is the so-called *voxel,* which is a three-dimensional volume element (in digital photography, a pixel refers to a two-dimensional picture element). In fMRI, voxels usually measure between 3 and 5 mm on each side and up to 50,000 voxels create an image of the whole brain.

Depending on the overall length of the experiment, the investigator acquires data from 500 to 1500 time points for each voxel. Because the BOLD signals in each voxel can be spatially and temporally correlated, certain preprocessing steps are necessary during data analysis (a detailed procedure of preprocessing and analyzing voxel-based fMRI data follows). Finally, since the brain is imaged in slices (i.e., planar regions), researchers should report details about the number of slices, the thickness of each slice (usually 5 mm), and the gap between slices (usually < 0.1 mm). Since fMRI has limited temporal resolution, marketing stimuli that are presented for less than one to two seconds might be more difficult to distinguish.

Summarizing, consumer fMRI researchers should supply details about the hemodynamic response model applied to the acquired data. Different software packages use different HRF models, such as *BrainVoyager*'s canonical HRF, *FSL*'s canonical gamma HRF, and *SPM*'s canonical difference of gammas HRF. Furthermore, research reports should provide information about the basis of the HRF or the method for estimating the HRF.

Experimental Procedure

During a typical fMRI experiment, the participant lies horizontally on a stretcher, which is moved into the fMRI scanner. Experiments carried out within the scanner typically last one hour. In the first stage, so-called *shimming* is performed, which is essentially the correction of inhomogeneities in the static magnetic field. These inhomogeneities may be caused by imperfections in the magnet or by the presence of external objects, including the participant's body. Second, *functional data* are collected while the participant engages in experimental tasks. Participants act behaviorally by pressing buttons on a response box. Finally, several high-resolution *structural scans* of the brain are conducted. These structural scans generate high-quality images over which the functional images will be laid for data analysis. During the structural scans, the subject does not perform any tasks.

In summary, consumer research using fMRI should provide information about the instructions subjects received before the actual brain scan as well as information about the stimuli (i.e., number of trials, number of repetitions, and number of different conditions). The researcher should also report whether and how behavioral responses were recorded. Usually, presentation software

allows for measuring the button press and also the reaction time from the onset of the stimulus presentation to the actual button press. Both variables—choice and reaction time—might serve as important information, which can later be analyzed together with neuroimaging data.

THE BRAIN AND CONSUMER RESEARCH

Consumer neuroscience investigations find that several stimuli result in specific brain activation, including the presentation of advertisements, product packaging, pricing, and brands. Table 1 presents an overview of these results. In relation to this overview, the following section provides a discussion of the neuroanatomical framework underlying consumer decision making.

Insights from Consumer Neuroscience Research Applying fMRI

Advertisement. One branch of studies focuses on the neurophysiological responses of subjects confronted with advertisements with differing content. For example, one investigation found that testimonials—in contrast to unknown people or to a brand logo—elicit stronger emotional and memory-related brain activation (Weis et al., 2006).

Product. A second branch of studies focuses on product design and its ability to elicit specific reactions in consumers. For example, one study illustrated the effect of product design (sports cars vs. compact cars) on specific brain areas. Results showed that the processing of status symbols triggers a reward effect, which influences the attitude toward the product (Erk et al., 2002). Another investigation compared aesthetic versus standardized product packaging design and found that aesthetic packages result in increased activation in the nucleus accumbens and the ventromedial prefrontal cortex, suggesting that reward value plays an important role in aesthetic product experiences (Reimann et al., 2010).

Price. A third stream of research in consumer neuroscience focuses on pricing. For example, participants sequentially saw products and associated prices in the brain scanner, and then indicated whether they would buy the product (Knutson et al., 2007). This study identified the activation of different brain areas in the trade-off between the "wanting" of a product and the "loss" of money. In addition, this study was the first to attempt to predict actual purchasing behavior of each participant during the presentation of the product, demonstrating the possibility of predicting individual behavior on the basis of brain activation.

Brand. Many consumer neuroscience research studies have concentrated on brands. For example, investigators examined whether neural correlates thought to be critical for emotional memories are involved in preference judgments regarding brands of soft drinks (Paulus & Frank, 2003). Results showed a significant activation in the ventromedial prefrontal cortex during preference judgment trials. Another study found that displaying logos of culturally familiar car brands activated the medial prefrontal cortex, a brain area that has been associated with

Table 1. Overview of fMRI Studies Focusing on Consumer Neuroscience.

General Area/Study Citation	Focal Topic	Substantive Findings and Corresponding Activations
Advertisement		
Weis et al. (2006)	Product memory	Testimonials (relative to unfamiliar people or a brand logo) influence stronger activation in brain regions associated with memory functions and emotions (inferior prefrontal cortex, right hippocampus, right amygdala).
Klucharev, Smidts, & Fernandez (2008)	Product memory	Caudate activity (prefrontal cortex, hippocampus, parahippocampal gyrus, caudate nucleus) mediates persuasive effect of experts.
Product		
Erk et al. (2002)	Reward through status, attitude toward product	Status symbols trigger reward response (ventral striatum, orbitofrontal cortex, anterior cingulate cortex).
McClure et al. (2004)	Taste perception, reward effects for preferred brands	Brands differentially influence taste perception (ventromedial prefrontal cortex, hippocampus, dorsolateral prefrontal cortex).
Reimann et al. (2010)	Packaging design	Aesthetic packages are highly rewarding (nucleus accumbens, ventromedial prefrontal cortex).
Price		
Knutson et al. (2007)	Purchases	Purchase decisions involve trade-off between wanting of product (nucleus accumbens) and loss of money (medial prefrontal cortex, insula).
Plassmann, O'Doherty, & Rangel (2007)	Willingness to pay	Medial orbitofrontal cortex codes willingness to pay.
Plassmann et al. (2008)	Pricing and experienced pleasantness	Price differentially influences taste perception (medial orbitofrontal cortex).
Brand		
Paulus & Frank (2003)	Brand preference	Medial prefrontal cortex, anterior cingulate cortex, left anterior insula play a critical role in preference judgments.
Deppe et al. (2005b)	Information processing, reward effects for preferred brands	Nonlinear winner-take-all effect for favorite brand characterized, on the one hand, by reduced activation in brain areas associated with working memory and reasoning (anterior cingulate cortex) and, on the other hand, increased activation in areas involved in processing of emotions and self-reflections (ventromedial prefrontal cortex).

(*Continued*)

Table 1. ***(Continued)*.**

General Area/Study Citation	Focal Topic	Substantive Findings and Corresponding Activations
Deppe et al. (2005a)	Brand credibility	Structures particularly involved in processing emotions (medial prefrontal cortex) also play a key role in the integration of implicit decision relevant framing information during decision making.
Schaefer et al. (2006)	Brand choice	Culturally familiar brands are rooted in self-reflection and self-relevant processing (medial prefrontal cortex).
Yoon et al. (2006)	Brand personality	Person judgments and product judgments are not processed in the same brain regions (medial prefrontal cortex for persons; left inferior prefrontal cortex for products).
Sales		
Dietvorst et al. (2009)	Interpersonal mentalizing between salespeople and customers	Using a new survey scale for interpersonal mentalizing (IM) to split the sample into low- and high-IM groups, the high-IM group had significantly stronger activation in brain regions that were previously associated with interpersonal mentalizing (right medial prefrontal cortex, temporo-parietal junctions).
Choice		
Hedgcock & Rao (2009)	Trading off decisions between choices, attraction effect	The presence of a third (normatively irrelevant) alternative yields relatively less activation in areas associated with negative emotion (medial prefrontal cortex, dorsolateral prefrontal cortex, anterior cingulate cortex, amygdala, right inferior parietal lobe) than the activation during choice tasks involving two equally (un)attractive options.

Note: Technical terms: *anterior* or *rostral* refers to areas in the front of the brain; *posterior* or *caudal* refers to areas in the rear of the brain; *superior* or *dorsal* describes the upper part of the brain; *inferior* or *ventral* refers to the lower part of the brain; *medial* refers to the middle of the brain; *lateral* means away from the middle.

self-reflection and self-relevant processing, and concluded that imagining the driving of a familiar car led participants to develop self-relevant thoughts (Schaefer et al., 2006). A third investigation used fMRI to investigate the perception of personality of brands versus the personality of faces and showed that the areas of processing differ between person and brand judgments, a result the investigators interpreted as challenging the concept of brand personality (Yoon et al., 2006). Finally, an fMRI experiment investigated reactions to drinking Pepsi versus Coke (McClure et al., 2004). When subjects were informed that they had received their preferred brand, reward centers were activated. The investigators concluded that the implicit and inherent associations to the product, rather than the product itself, are responsible for the brain's reaction—or at least these associations influence the experience of the sensory information.

These studies suggest that brand name information may act as an emotional-memory–based somatic marker in preference judgments. Related findings indicate that preferred brands—by comparison with non-preferred brands—show less brain activation in areas which are involved in working memory and reasoning, but increased activation in the reward-related ventromedial prefrontal cortex (Deppe et al., 2005b). A follow-up study investigated the influence of brand credibility on the perception of information associated with the brand (Deppe et al., 2005a). The study used a framing manipulation, implemented by varying credibility of news magazines, to show the different susceptibility of individual subjects to the framing of the information, which was shown to be associated with differing ventromedial prefrontal cortex activation.

Understanding the Neuroanatomical Framework of Consumer Decision Making

Some publications in the popular press claim that "buy buttons" exist in the brain (Lindstrom & Underhill, 2010; Renvoisé & Morin, 2007). However, controversy persists regarding the presence of such a "one-and-only" choice-triggering mechanism. Although the brain's mesolimbic dopamine system (also often referred to as the "reward system") provides a powerful explanation for human wanting of a variety of stimuli, ranging from drugs (Wise & Rompre, 1989), food (Berridge, 1996), and money (Knutson et al., 2001) to aesthetically packaged products (Reimann et al., 2010), the dopamine system is a mechanism that responds to subjectively attractive rewards. The subjectively platitudinous "beauty in the eye of the beholder" may lead to dopamine release, a rewarding experience, and choice of the rewarding stimulus. Therefore, the road from creating rewarding stimuli (e.g., a beautiful product design) through the consumer's brain to actual consumer choice is a long one. For example, not every computer manufacturer has the design capabilities of Apple to create attractive MacBooks, iPhones, and iPads. In addition, not every consumer can appreciate the Apple design and, therefore, be rewarded by it. Researchers mainly agree that many brain functions depend on scattered networks and that single brain areas may contribute to more than one function (Loewenstein, Rick, & Cohen, 2008).

Consumer neuroscience studies find several brain areas to be important to consumer neuroscience research. The *striatum* consists of different subareas, most importantly the *putamen*, the *caudate nucleus*, and the *nucleus accumben*s. Previous studies have demonstrated the importance of the striatum and

its subareas in (1) goal-directed evaluation of affective stimuli (Delgado, 2007), especially in reward-related learning (Cohen et al., 2007; Galvan et al., 2005); (2) the coding of deviations of actual rewards from expectations (Knutson & Wimmer, 2007); and (3) the influence of social factors on reward processing in the striatum (Delgado, Frank, & Phelps, 2005; Fliessbach et al., 2007). Additional investigations suggested that the striatum also codes product preference in purchase decisions (Knutson et al., 2007) and illustrated that the striatum could also be a surrogate marker of effective product design (Erk et al., 2002; Reimann et al., 2010).

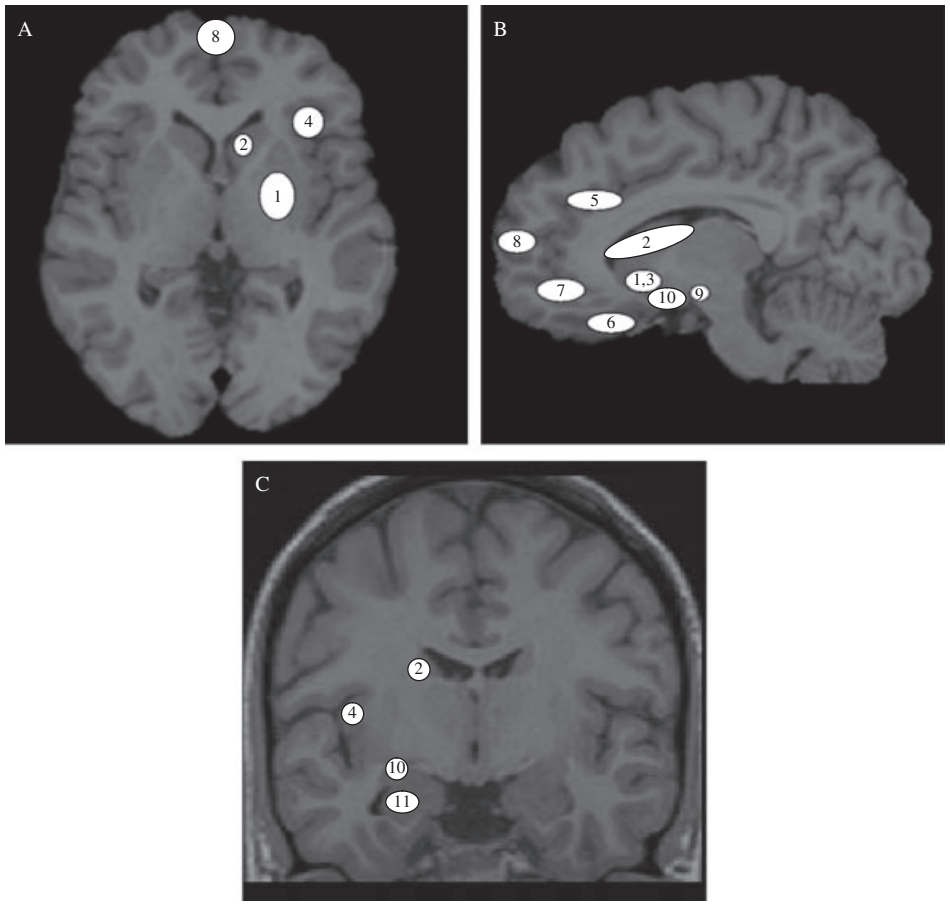
The *insula* is another important brain area linked to consumer decision making. Specifically, negative reinforcement such as losing money, social frustration, or expected risk seems to activate the insula. Prior research associated insula activation with the price that participants had to pay for a product—the higher the price, the larger the activation (Knutson et al., 2007)—and expected risk of a financial decision (Knutson & Bossaerts, 2007). In summary, while other brain areas often are involved in expecting or processing positive experiences, the insula seems to code negative events.

The *anterior cingulate cortex* (ACC) has been related to brand preference (Paulus & Frank, 2003). The *orbitofrontal cortex* (OFC) and the closely related *ventromedial prefrontal cortex* (VMPFC) have been shown to code the perceived value of different possible outcomes (Tremblay & Schultz, 1999; Wallis & Miller, 2003). While the more medial regions of the OFC and VMPFC seem to be associated with rewarding outcomes, the more lateral parts evaluate punishing cues (O'Doherty et al., 2001). Overall, the OFC integrates sensory and affective information from different regions of the brain to derive the value of a potential reward outcome, including the assessment of trade-offs and the determination of how well the outcome will meet actual needs (Kringelbach, 2005; Wallis, 2007). This value information will be used by the *medial prefrontal cortex* (MPFC), an area which is linked to anticipated value (Amodio & Frith, 2006, p. 275). The MPFC also accounts for the effort of obtaining an outcome and for the likelihood of the success of an action (Wallis, 2007).

The *ventral tegmental area* (VTA) is largely responsible for transmitting dopamine into most brain areas. As a neurotransmitter (i.e., a chemical that carries communication signals between brain cells), dopamine modulates decision making, and the involvement of the VTA in motivation has been well established (Fields et al., 2007). A recent study looked at the role of the VTA in the processing of novel stimuli as well as expected rewards (Wittmann et al., 2007). In summary, the VTA may be important for reward and novelty processing of advertising or brand-related stimuli.

The *amygdala* is linked to negative emotional processing. In recent years, studies have increasingly shown that the amygdala also plays an important role in the processing of positive stimuli and rewards (Murray, 2007). Apparently, amygdala activation signals the salience of a stimulus and leads to an arousal effect. Activation of the amygdala—whether in the sense of negative emotional processing or of stimulus salience—is an important modulator of the memory system and, thus, of importance for the evaluation of marketing stimuli and their encoding in long-term memory (Weis et al., 2006).

The *hippocampus* plays a major role in memory, and prior studies have shown that the hippocampus may be linked to product memory (Klucharev, Smidts, & Fernandez, 2008; Weis et al., 2006) and taste memory (McClure et al., 2004).



Note: A: *Horizontal* or *axial* slice through the brain; B: *sagittal* or *sideways* slice; C: *coronal* or *frontal* slice; 1: putamen, 2: caudate nucleus; 3: nucleus accumbens; 4: right anterior insula; 5: anterior cingulate cortex (ACC); 6: orbitofrontal cortex (OFC); 7: ventromedical prefrontal cortex (VMPFC); 8: medical prefrontal cortex (MPFC); 9: ventral tegmental area (VTA); 10: amygdala; and 11: hippocampus.

Figure 1. Associated brain areas in consumer neuroscience research.

Figure 1 illustrates identified brain areas in previous consumer neuroscience research using fMRI.

PROCEDURES FOR THE APPLICATION OF fMRI IN CONSUMER RESEARCH

Researchers applying fMRI should be aware of the complexities of data acquisition and analysis and how to deal with them in a consumer research study. Specifically, optimal data acquisition depends on many different parameter settings and equipment design factors. Moreover, inferences strongly depend on data quality.

This study proposes four steps as being critical to successful fMRI applications: (1) conceptualization and operationalization of the research context; (2) data acquisition; (3) data analysis; and (4) triangulation (Figure 2). An fMRI

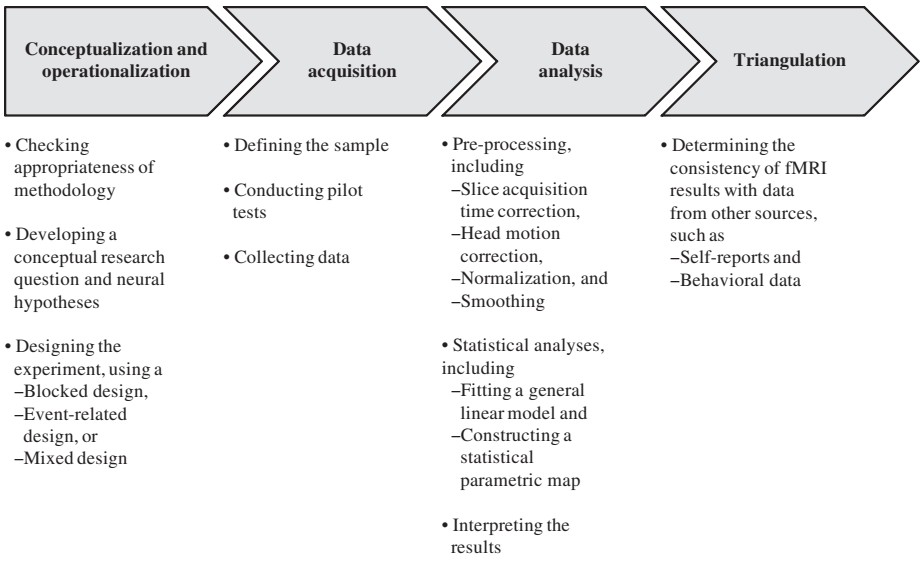


Figure 2. Suggested steps for the application of fMRI in consumer research.

experiment that collected empirical data from 16 participants will illustrate these steps (also see Weber et al., 2007 for more detailed reporting).

The research question of the fMRI study in this investigation was whether emotional attachment mediates the relationship between intention to trade a product and loss aversion, an issue that others have raised previously in the marketing literature (Ariely, Huber, & Wertenbroch, 2005; Brenner et al., 2007; Nayakankuppam & Mishra, 2005; Novemsky & Kahneman, 2005b; Strahilevitz & Loewenstein, 1998; Zhang & Fishbach, 2005). Prior research has labeled this phenomenon the endowment effect (Thaler, 1980)—the effect that the value of a product to an individual appears to be higher when the individual perceives the product as something that could be lost, as opposed to something offering a potential gain (Kahneman, Knetsch, & Thaler, 1990, 1991). From a purely economic perspective, the endowment effect thus represents an anomaly that violates the assumption of reference-independence in rational choice theories (Tversky & Kahneman, 1991).

Conceptualization and Operationalization

Appropriateness Check of Methodology. While the marketing literature has given considerable attention to the question of whether loss aversion accompanies routine purchases (Ariely, Huber, & Wertenbroch, 2005; Camerer, Loewenstein, & Prelec, 2005; Novemsky & Kahneman, 2005a), prior research using behavioral experiments has yielded inconclusive results (Bateman, 2005). This caveat is based on the notion that behavior may not be a clear indicator of emotional processes producing the endowment effect.

Brain imaging is a method that can more directly analyze such emotional processes (Wager et al., 2003). Specifically, fMRI has proven capable of detecting negative human emotions in the brain, such as fear in the amygdala (LeDoux, 2000; Phelps et al., 2001). Also, fMRI seems particularly suitable since investigators have used it to identify correlates to the anticipation of economic loss (Breiter

et al., 2001; Kuhnen & Knutson, 2005; Trepel, Fox, & Poldrack, 2005). For these reasons, fMRI is appropriate for studying issues related to loss aversion.

Development of the Research Question and Hypotheses. Ideally, a study starts with a single research question, accompanied by a limited number of related hypotheses, to fully map the brain's activity. In the present study, the research question was, "Is the link between the intention to give something up and loss aversion mediated by emotional attachment?"

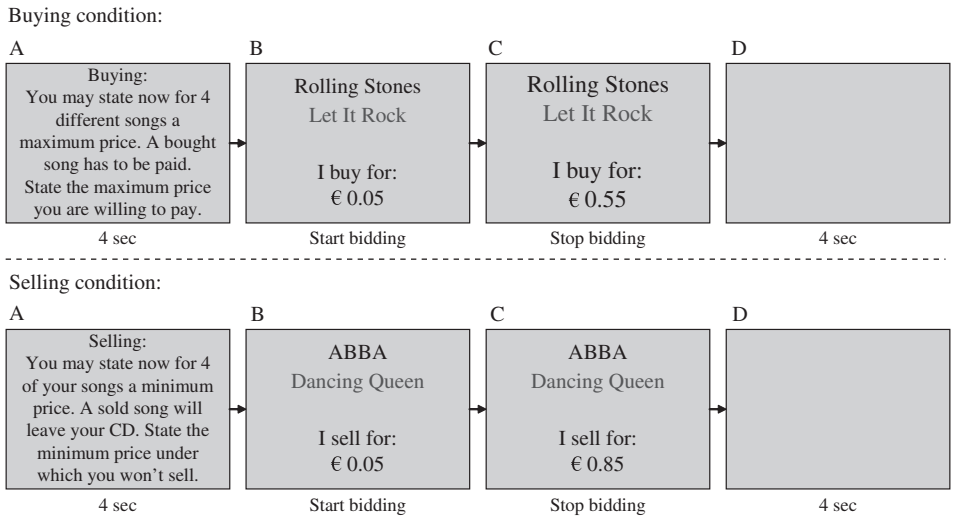
Previous investigators suggest applying fMRI to analyze the loci of brain activity and determine "whether emotional attachment is indeed related to loss aversion and whether it mediates the effects of intentions on loss aversion" (Novemsky & Kahneman, 2005b, p. 140). Therefore, this study applied fMRI to the links between intentions, emotional attachment, and loss aversion. FMRI affords the possibility of identifying reference-dependent accounts of the endowment effect. Specifically, the literature in both cognitive neuroscience and marketing suggests that loss aversion is related to negative emotions such as fear (Camerer, Loewenstein, & Prelec, 2005, p. 139). This relationship implies that high loss aversion is associated with increased activity in brain areas related to negative emotions in decision making, specifically the amygdala (Hariri et al., 2002; Trepel, Fox, & Poldrack, 2005). Thus, emotional attachment should be more evident when selling a product than when buying it. Consequently, it is hypothesized:

H1: Selling a product compared to buying a product results in stronger neural activity in brain regions associated with the processing of negative emotions.

Experimental Design. Over the years, two basic design concepts have emerged for fMRI: *blocked designs* and *event-related designs* (Dale, 1999). Blocked designs separate experimental conditions into distinct time intervals (blocks). Thus, a certain number of stimuli of the same category build a block of stimuli. This design type proves to be robust in detecting active voxels in the brain (high detection power) and in examining state changes between one condition and another. However, it offers poor estimation power (i.e., the time course of an active voxel is difficult to predict).

Event-related designs present discrete, short-duration events. The timing and order of these events are randomized. This type of design offers good estimation power and allows for the determination of change from the baseline, but it also can result in limited detection power. The major advantage of an event-related design is its ability to analyze individual events not based on blocks defined *a priori,* but on the decisions that participants make either during or after the experiment. For example, an event-related design allows for the analysis of brain activation of later-bought products in comparison to not-bought products, which is not possible with a blocked design. In addition to blocked and event-related designs, *mixed designs* are possible. Mixed designs offer a balanced emphasis on detection and estimation, but also result in the highest level of complexity during analysis (Huettel, Song, & McCarthy, 2004).

Another issue in the design of an fMRI experiment is the number of manipulations. Too many manipulations impair the pinpoint focus of the experiment as well as the statistical interpretation of data. Limiting the number of factors has two advantages: First, the experiment is less confusing since fewer stimuli are



Note: The buying and selling condition changed after every four songs. (A) Each buying and selling session started with identical information on the subsequent task (duration: 4 sec). (B) Both the buying and selling process started with a bid of 5 cents. (C) Participants could increase their bids by pushing buttons on response grips. (D) After participants finalized their bidding by pressing a specific button, a pause (duration: 4 sec) followed to normalize brain activities.

Figure 3. Sample of trial stimuli.

repeated, and second, the total length of the experiment is shorter, lessening participant fatigue. An insufficient number of trials per condition lowers the statistical power and later impairs the explanatory power of the results owing to the low signal-to-noise ratio in fMRI. The *signal-to-noise ratio* is the strength of a signal (that is, changes in magnetization) relative to other sources of variability in the data (Huettel et al., 2004). Although researchers do not agree on a standard number of repetitions, at least 25 repetitions of identical mental processes (i.e., trials) per condition are recommended to ensure reliability.

The present experimental study used two treatments. In the first, participants were asked to sell a product (high loss aversion was expected) and in the second, they were asked to buy a product (lower loss aversion was expected). The two treatments were counterbalanced over the course of the experiment. To achieve greater robustness and shorter scanning time, this study was performed using a blocked design. Because of the low signal-to-noise ratio inherent in fMRI, 32 repetitions were used for each of the two treatments.

Traded products in this study were MP3 songs, as they are highly emotion-arousing, inexpensive, and approximately homogeneous. To ensure high individual relevance of the specific songs, two months before the actual study took place subjects selected 73 songs from the Web site of a music platform and provided information on subjective monetary value and emotional attachment for each song. This information led to exclusion of one person, who ascribed no monetary value to any of the songs. The 73 individually selected songs were then revised to a shorter list of 64 songs for each participant. A multi-step paradigm was designed using the software *Presentation* (Neurobehavioral Systems, Inc.). Figure 3 shows a sample of trial stimuli.

For each transaction, the name of the artist and song were presented to the participant. Subsequently, participants bid for the songs according to the BDM auction mechanism (Becker, DeGroot, & Marschak, 1964) while undergoing

fMRI scanning. In each selling condition, participants stated their willingness to accept (WTA; i.e., minimum price), and in each buying condition they expressed their willingness to pay (WTP; i.e., maximum price) by pressing buttons on response grips.

The most accepted explanation for the discrepancy between WTA and WTP is loss aversion (Knetsch, Tang, & Thaler, 2001; Tom, Lopez, & Demir, 2006; van de Ven, Zeelenberg, & van Dijk, 2005). Loss aversion for money (buying condition) was maximized by asking subjects to bring their own money to the experiment and by trading songs for real cash, since cash payment intensifies the emotional reaction to the payment (Soman, 2001). The experimental design maximized loss aversion for goods (selling condition) via the song preselection process, thus ensuring high emotional attachment to the songs, which has been suggested to increase loss aversion (Ariely, Huber, & Wertenbroch, 2005; Peters, Slovic, & Gregory, 2003).

The presented experimental design also controlled for several alternative explanations for the WTA–WTP gap. The first is a lack of substitutability (Hanemann, 1991; Shogren et al., 1994), as, for example, when analyzing the trade-off between health and money. In this experiment, participants were aware that the traded songs were also available in music stores. Furthermore, participants would have minimal search costs on the store's Web site, since they had already searched for and found the songs before. Therefore, subjects had an easy way to substitute songs they sold or did not buy during the experiment.

A second, related explanation for the WTA–WTP gap is based on an income effect (Horowitz & McConnell, 2003). The chosen experimental design controlled for an income effect by leveling out the money participants spent in buying with the money they earned in selling. This approach minimized participants' need to consider budget restrictions. Additionally, the products that were traded were of low cost.

A third explanation for the WTA–WTP gap relates to misconceptions of the trading mechanism (Plott & Zeiler, 2005) or bargaining behavior (Kahneman, Knetsch, & Thaler, 1991). To prevent misunderstandings, participants were extensively trained in the briefing phase. The behavioral data provide evidence that no learning effects took place during the experiment, since the order of the presentation of the stimuli did not significantly correlate with the height of bidding in both conditions (buying: $r = -0.06$, n.s., $n = 512$; selling: $r = 0.06$, n.s., $n = 512$). Also, the BDM mechanism may prevent bargaining behavior and has been used in similar studies (e.g., Novemsky & Kahneman, 2005a). Thus, the experimental design minimized alternate explanations for the WTA–WTP gap other than loss aversion.

Data Collection

Sample. A common problem with fMRI studies is small sample size, a dilemma that is largely due to the cost of scan time. Problems that arise with a small sample size are a small signal-to-noise ratio when measuring brain activity and individual differences in activation levels and neuroanatomy. Although no consensus exists as to a minimum sample size for fMRI experiments, a rule of thumb is that, to aim for high internal validity, at least 15 participants should be recruited. Prior to scanning, participants should be asked if they take any medication and if they have had a brain injury, as brain imaging data can be biased by drug intake or lesions.[1]

[1] A sample fMRI screening form can be obtained from Shellock and Crues (2004).

Sixteen healthy individuals were screened and enrolled in the present study (10 males, 6 females; mean age: 25 years). To control for lateralization differences in brain responses, all selected individuals were right-handed according to the Edinburgh Handedness Scale (Oldfield, 1971).

Pilot Testing. In a pilot-testing phase, participants should be asked questions about the tasks and trials pertaining to whether they feel bored or overstrained, whether the timing of the trials is too slow or too fast, and whether they are able to clearly see and read the stimuli and task description. Another recommendation is to analyze the results from the first subject completely before scanning others, to see whether the paradigm suits the processes of interest in the brain. In the present study, tasks were piloted extensively with 15 participants to ensure high data quality.

Data Collection. In presenting stimuli to participants in the brain scanner, the investigator just uses fMRI-compatible, nonmagnetic equipment. In a frequently used technique for presenting visual stimuli, a video projector reflects stimuli onto a mirror. This mirror is installed in the fMRI scanner right above the participant's head. Alternatively, nonferrous video goggles can be used. Audible stimuli can be presented via nonmagnetic headphones. Besides visual and audible stimuli, prior research has offered gustatory and olfactory stimuli (Marciani et al., 2006). Commonly used devices to collect data include response boxes, response grips, and joysticks. Participants' heads should rest on vacuum cushions or memory foam to achieve maximal comfort and minimal head movement.

The present study showed stimuli via video goggles, and participants used two response grips (NordicNeuroLab) within the brain scanner to buy and sell MP3 songs. To minimize learning effects over the course of the brain scans, participants were trained in the use of this equipment two weeks in advance as well as during the briefing session.

In the buying condition, bids started at five cents and participants could increase their bid by pressing the response grips. In the selling condition, prices also started at five cents. Again, participants were able to increase the selling price via the response grips. At the end of the experiment, all participants received the songs they had bought and not sold back on a CD-ROM. Other important technical parameters of the data collection are the following: scanning time, approximately 30 min; scanner model, 1.5-tesla Siemens Avanto, using a standard head coil; number of slices, 45; slice thickness, 3 mm; gap between slices, 0.3 mm; matrix size, 64×64; field of view, 195 mm; repetition time, 2.98 sec; and echo time, 45 ms. These parameters are standard for functional imaging acquisitions on a 1.5-tesla scanner. The repetition time results from the amount of time necessary to acquire 45 slices at an echo time of 45 ms, which is in a typical range (Weiskopf et al., 2006). A gap between the slices of approximately 10% is typically used to minimize noise between slices.

Data Analysis

Preprocessing. Preprocessing of fMRI data encompasses a set of procedures conducted prior to statistical data analysis (i.e., model fitting) to reduce variability in the data not associated with the experiment. The literature discusses four

commonly used preprocessing steps: slice acquisition time correction, head motion correction, normalization, and smoothing (Huettel, Song, & McCarthy, 2004).

Slice acquisition time correction addresses the fact that different slices within a single image of the complete brain are acquired one after another, and not at the exact same time. During a typical pulse sequence and within a repetition time of between 1.5 and 3 sec, more than 24 slices covering the entire brain are acquired. Each slice takes about 100 ms to acquire, but the software used to analyze the volumes assumes that the slices are acquired at the same time. To compensate for these differences in acquisition time, the time series is interpolated in each voxel of every slice according to a reference slice (usually the slice acquired at mid-TR). More recent discussions suggest that slice timing is not generally recommended and may be removed from preprocessing steps in the future (Ashburner et al., 2010).

Head motion correction relates to the common problem of participants moving while in the scanner. An important consideration is to control motion parameters for every subject by adjusting the time series of images, so that the brain is in exactly the same position on each brain image. This consistency can be achieved by spatially aligning two images to a target image. Cases with excessive head motion should be excluded. As a threshold for head motions, subjects should not move more than one voxel during the experiment. At data collection a subject can be stabilized with memory foam (i.e., the subject's head is surrounded by foam) or with a head coil–mounted plastic bite bar (i.e., the subject's teeth are molded in a hardening matter).

Normalization must be performed because individual brains differ in size and shape. Therefore, transforming individual brain data into a standardized template brain is necessary. Transformation enables the comparison of functionally analogous regions between subjects despite anatomical differences. The process of normalization is based on linear and nonlinear transformations of the original image to morph it to a standardized template. A recent study compared different normalization algorithms, which may be informative to the reader (Klein et al., 2009).

Smoothing is used to remove noise in the data while preserving signals of interest. The most common smoothing method is the Gaussian filter (also termed the Gaussian kernel), which has the shape of a normal distribution. The Gaussian filter blurs the brain image and spreads the intensity of each voxel in the image over nearby voxels. In addition, it leads to a more normal distribution of the data, which is a prerequisite for later parametric statistical tests. The width of the filter can be adjusted and should be defined by the brain areas of interest. Wide filters spread data over many voxels and narrow filters spread data over only a few voxels (for a more detailed description of smoothing effects on fMRI data see, e.g., Mikl et al., 2008).

In the current study, preprocessing started with slice acquisition time correction. The hemodynamic response to each transaction (i.e., buying or selling a song) was modeled by means of a canonical hemodynamic response function and the temporal derivative. The canonical hemodynamic response function implemented in the software package *SPM* is a standard hemodynamic response expected after neural activity. Head motion correction, normalization to the reference brain of the Montreal Neurological Institute (often referred to as the MNI template, or the echo planar image or EPI template) and smoothing using a 12-mm Gaussian filter were conducted.

Statistical Analysis. After preprocessing the brain data and before conducting aggregate analyses on the level of brain regions, each voxel is first analyzed individually and independent of others. The goal is to identify those voxels for which the time series significantly correlates with a specific experimental condition. A common approach is to fit a general linear model (GLM) to the time series of each voxel. The GLM assumes that the measured time series is a linear combination of activity related to the different regressors of interest, as expressed in the following function.

$$Y = \beta X + \text{error}$$

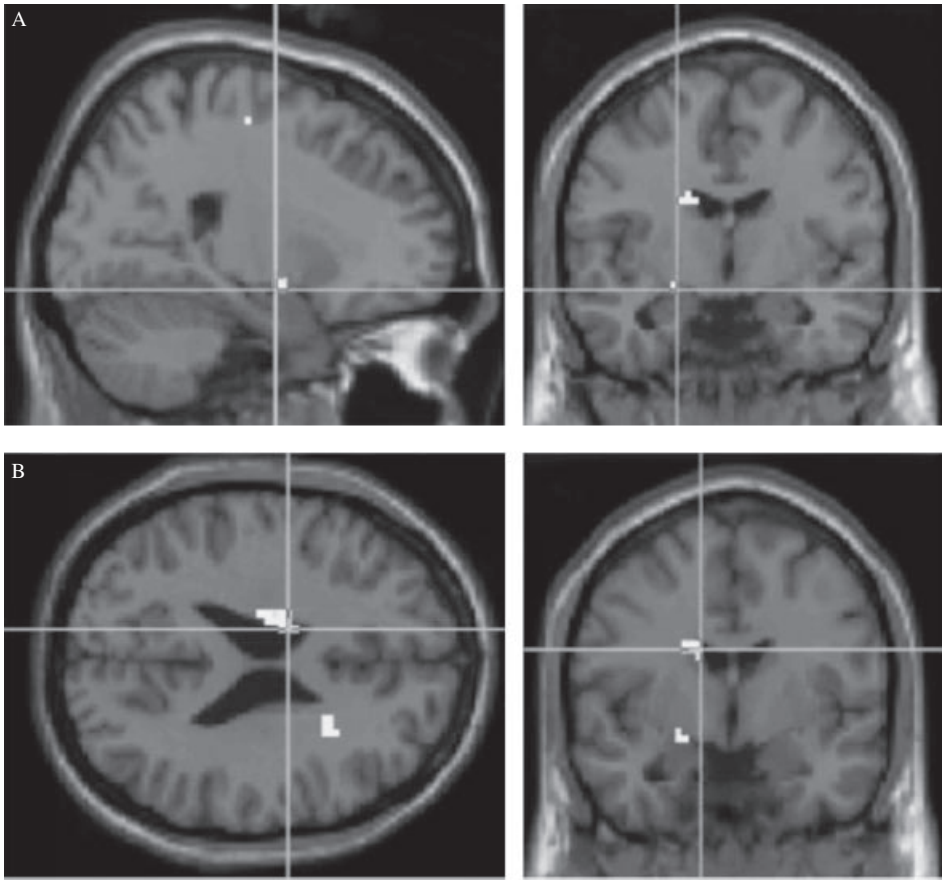
where Y = time series, β = parameter estimates, and X = design matrix.

These regressors are stick functions (or box functions in a block design) convolved with a set of basis functions to model the hemodynamic response. Once time series and experimental conditions have been fitted for every voxel, the voxels can be displayed together in a single brain image, the so-called *statistical parametric map*. The statistical parametric map is a three-dimensional map of the brain, consisting of voxelwise statistical information about the association between the analyzed condition and brain activity (by means of *t*-values; see Josephs, Turner, & Friston, 1997). The individual maps can then be overlaid on structural images to visualize which brain areas exhibit activity with respect to specific conditions.

Statistical thresholds are then applied to the statistical parametric map to provide colored activation maps displaying the degrees of significance for each voxel. Finally, the coordinates from the EPI template may be transformed into Talairach coordinates, a commonly used coordinate system of the human brain (Talairach & Tournoux, 1988, 1993). In most studies, investigation of single subjects is not of primary interest. Rather, the aim is to draw inferences about a population from which subjects were drawn. This approach is usually implemented by a random-effects model taking the mean estimated activity from individual subjects on a "second level."

In the present study, analyses were performed using the software *Statistical Parametric Mapping 2.* For model fitting, two vectors of stimulus onsets were used (i.e., the buying condition and the selling condition). A parameter image for this contrast was generated for each participant and was subjected to a second-level random effects analysis, using one-way ANOVA (within subject). Predefined linear combinations of the group contrast images then were tested using a one-sample *t*-test against a null hypothesis of no effect. The statistical threshold for denoting the activity of a specific brain area was set at $p < 0.05$ ($p < 0.001$ for each individual voxel). A main result of the analyses was a significantly stronger activation in the amygdala while the subject was estimating the selling price versus the buying price ($p < 0.05$). Additionally, a comparison of the baseline condition (i.e., pause between stimuli) to the buying condition revealed no significant activation in the amygdala in the buying condition, but significant activation in the selling condition ($p < 0.05$). Further, the analyses showed significantly more activation in the caudate nucleus during the selling condition (see Figure 4).

Data Interpretation. The findings suggest that amygdala activation mediates the relationship between buying or selling intentions and buying or selling choice. The activation during the selling condition in comparison to the buying



Note: The amygdala (A) and the caudate nucleus (B) are significantly more active during the selling condition than during the buying condition (at $p < 0.001$, uncorrected). Marked by crosshairs, the amygdala is shown sagittally (i.e., sideways) in the upper left picture and coronally (i.e., frontally) in the upper right image, and the caudate nucleus is presented horizontally (i.e., axially) in the lower left image and coronally in the lower right picture.

Figure 4. Results.

condition cannot be attributed to variation in reaction times; no difference was observed in the reaction to selling and buying decisions [$F(1,1022) = 0.003$, n.s.]. In summary, results supported hypothesis H1, which stated that neural activity occurs in brain regions associated with the processing of fear (here, amygdala activation) when selling a product, whereas no such activity occurs when buying a product during a routine transaction.

The present study sought to determine neural correlates of the endowment effect by measuring loss aversion during buying and selling of products. In line with prior neuroscience research (Camerer, Loewenstein, & Prelec, 2005; Hariri et al., 2002; Trepel, Fox, & Poldrack, 2005), the amygdala activation in the selling condition can be interpreted as an indicator of the presence of loss aversion, and the absence of amygdala activation in the buying condition as an indicator of the absence of loss aversion. As proposed by Trepel, Fox, and Poldrack (2005), the anticipation of a loss—that is, selling a product—evokes negative emotional responses, whereas losing money—buying a product—does not. This result supports prior consumer research, which suggests such an effect and calls for future

research on underlying neural mechanisms (Novemsky & Kahneman, 2005b). As significantly more caudate nucleus activation occurred in the selling than in the buying condition, the notion that attachment to the product may also have a reward value is supported (Strahilevitz & Loewenstein, 1998). Finally, these results complement findings on the endowment effect in terms of greater nucleus accumbens activation for preferred products across buying and selling conditions combined, greater medial prefrontal cortex activation in response to low prices when buying versus selling, and right insular activation during selling. However, results did not reveal amygdala or caudate activation (Knutson et al., 2008).

As discussed above, researchers should use caution in making reverse inferences, that is, concluding that a specific brain function—such as loss aversion—is based on the activation of an identified brain area—such as the amygdala (Poldrack, 2006). Reverse inferring was addressed in the following ways: (1) The use of prior findings and existing theory on a specific brain area and its function on the one hand and the urge to explore potentially new areas on the other hand were balanced by carefully considering existing neural theories; (2) evidence that the findings reflect current neuroscientific literature was provided; (3) each step of the employed task was carefully linked with the neuroimaging data; and, finally, (4) all relevant task characteristics were reported.

Triangulation

The final step, *data triangulation,* is also known as *convergent validation.* This step consists of collecting complementary data sources, including self-reports and behavioral data, and linking them with fMRI data. In the current study, brain data, self-reported data, and behavioral data were triangulated. After the fMRI scan, participants described their feelings pertaining to the selling and buying conditions. With respect to the selling condition, participants expressed feelings of fear, such as "I did not want to lose my song when it was already in my possession" or "Giving up a song felt harder than not getting one." Moreover, results showed that selling prices were significantly higher than buying prices [buying condition: $M = €0.51$, SD = 0.32; selling condition $M = €1.21$, SD = 0.89; buying condition vs. selling condition: $F(1,1022) = 283.4$, $p < 0.001$]. These findings were consistent with greater amygdala activation in the selling condition.

The aforementioned steps and the recommendations put forward by Poldrack et al. (2008) suggest that the information summarized in Table 2 should be reported in the paper. Reporting guidelines may need to be adapted to the specific characteristics of individual studies and may change over time as technologies become more advanced.

SUMMARY AND CONCLUSION

The goal of this paper is to review the state of the art of fMRI in consumer neuroscience and to lay the groundwork for future applications of fMRI in consumer and marketing research. The paper offers three thoughts to stimulate further research and debate. First, as fMRI is becoming an increasingly accepted and applied methodology in consumer research, the authors expect future studies to

Table 2. Reporting Guidelines (Based on Huettel, Song, & McCarthy, 2004; Poldrack et al., 2008).

Step	Issues to Be Reported
Conceptualization/ operationalization	• How was fMRI expected to enhance prior findings? • How are prior fMRI studies relevant to the research question? • What was the theoretical research question? • What were the neural hypotheses? • How many blocks, trials, or experimental units per session/subject? • What was the length of each trial? • Blocked designs: How long were the blocks? • Event-related designs: How was the design optimized for efficiency? • Mixed designs: What was the correlation between block and event regressors? • What instructions were given to the subjects? • What stimuli were used and how were they implemented? • What conditions were planned to be compared?
Data acquisition	• What was the sample size? • What were the age, handedness, and gender of the subjects? • Were any specific selection criteria used for subject recruitment? • Were any subjects scanned but then rejected from analysis? • Was a pilot test conducted? • How was behavioral performance measured (e.g., choice, reaction time)? • What equipment was used (stimuli presentation tools, behavioral response recording, scanner model)? • How many slices were acquired? What was the gap between slices? • What matrix size was used? • What was the field of view? • What specifications for repetition time and echo time were used?
Data analysis	• What software was used for data preprocessing? • Which preprocessing steps were performed (in which sequence and based on which technique)? • What software was used for the statistical analysis? • What statistical model and estimation methods were used? • What was the basis of the HRF or the method for estimating the HRF? • What contrast (between tasks/conditions) was constructed? • Was a within- or between-subjects methodology used? • What significance level was used as a threshold for depicting brain activity? • Could the null hypothesis be rejected (at what level of significance)? • What are the theoretical implications of the findings?
Triangulation	• Were the fMRI data consistent with subjects' self-reports? • Were the fMRI data consistent with behavioral measures?

shift in focus from mere identification of neural correlates to systematic prediction, theory testing, and theory building. Here, existing neurological theories (e.g., somatic marker theory) can assist in building sound theoretical models based on fMRI data (Reimann & Bechara, 2010). In particular, fMRI offers some striking advantages over classical research methods, especially when the fit between fMRI methodology and the research question is high, as when investigating affective processes (Ochsner & Gross, 2005). Of course, researchers should carefully consider and deal with the methodological limits, which are highlighted throughout this paper. By improving spatial and temporal resolution and by innovating methodological standards and establishing benchmarks, fMRI will no doubt become more common in marketing and consumer research.

Second, fMRI should not be regarded as a standalone methodology. Rather, future research should link fMRI data to measures collected via alternative methods, such as self-reports and behavioral data. This association may not only be useful for convergent validation purposes. It can also give rise to challenges of previous findings. Revealing inconsistencies in data derived from different methodologies might lead investigators to new, previously undiscovered insights into the processes underlying consumption decisions.

Finally, beyond emphasizing the complexities of careful experimental design and implementation, this review highlights the need for interdisciplinary collaboration and major grant support to sustain fMRI research programs. The potential for more valid measurement of conditions and processes that underlie decision making and consumption, and the exposure of new relationships, should foster neuroscientific research efforts in consumer research.

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