Applications of functional magnetic resonance imaging for market research

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Abstract

Purpose – The purpose of this paper is to provide a brief overview of the methodology of several brain imaging techniques and in particular, functional magnetic resonance imaging (fMRI) and its potential implications for market research. The aim is to enable the reader both to understand this emerging methodology and to conduct independent research in the area.

Design/methodology/approach – A short introduction on current neuroimaging methods used in behavioral neuroscience is provided by means of a literature review. The ensuing discussion focuses on fMRI as the currently most popular neuroimaging technique. Having described the fMRI methodology, an outline of the analysis of functional neuroimaging data follows, after which there is a discussion of some key research issues.

Findings – Although in its infancy, fMRI seems to be a useful and promising tool for market researchers. Initial studies in the field reveal that fMRI is able to shed light on subconscious processes such as affective aspects of consumer behavior.

Practical implications – Because brand positioning, advertising strategies and even pricing strategies are often based on constructs such as emotions, neuropsychological findings and methods should have important implications for practitioners in the field of brand management and advertising. Nonetheless, far more basic research is needed before fMRI can be adopted for marketing practice.

Originality/value – This paper is one of the first in the marketing literature to provide a methodological overview of fMRI and discuss the potential implications for marketing research.

Keywords Market research, Brain, Research methods

Paper type General review

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Towards a neuroscientific foundation for consumer research

Theories and models used in consumer research have changed dramatically over the last few years (Bagozzi et al., 1999; Zaltman, 2000). One focus has been the role of emotions which are ubiquitous throughout marketing (Bagozzi et al., 1999; Holbrook and Rajeev, 1987a; Thomson et al., 2005). Although, retroactively, conscious emotional information processing and perception have been studied extensively in consumer research, little is known about how marketing stimuli, e.g. brands, are processed by the human brain. The main benefit to both marketing research and practice of observing the brain in vivo during information processing procedures is that such subconscious processes as the intuitive integration of emotions can be investigated (Adolphs et al., 2005; Kenning and Plassmann, 2005). This can shed light on the role of emotions as a physiological state in marketing (Bagozzi et al., 1999; Hansen, 2005).

Initial approaches to measuring the response of the peripheral nervous system to marketing stimuli, such as electrodermal response or pupil dilation response measurement, were already applied in the 1970s. Their application still seems useful with respect to some specific research questions (Hess and Polt, 1960; Kroeber-Riel, 1979; Hansen, 1982; Klebba, 1985; Sundar and Kalyanaraman, 2004; Groeppel-Klein, 2005). In this context, methods for measuring electric brain waves have also been employed (Klebba, 1985; Rothschild et al., 1988; Rossiter et al., 2001a). These studies have contributed substantially to consumer research by measuring the amplitudes of neurophysiologic activation. However, due to methodological problems such as evaluating the valence (positive vs negative) of activations (Klebba, 1985), these studies have not satisfactorily answered the question of how consumers process emotional responses to such marketing stimuli as brand logos.

At present, technological innovations in the field of neuroimaging appear to override the methodological problems of the former approaches (Yoon et al., 2006). For instance, functional brain imaging methods facilitate the analysis of human brain functions while the subject decides simultaneously between several different brands (Deppe et al., 2005a) or the attractiveness of a particular car design (Erk et al., 2002). In these studies, through the use of neuroimaging techniques, the corresponding brain activity during experimental conditions of interest can be detected and the activation localized. In other words, with the use of neuroimaging techniques, one can see the “footprints of components of the functional architecture (of the brain) that are evoked during the task” (Kosslyn, 1999). The pool of results from past neuroscientific studies then facilitates linking a specific brain area to a possible function such as the amygdala to emotion processing, the insula to “disgust” or the striatum to “reward” (Berthoz et al., 2002; Sanfey et al., 2003; Frackowiak et al., 2004). In combination with other techniques, this may help to solve the valence problem mentioned above, because there is no need to ask the people about their feelings post-cognitively. Instead, the brain activity corresponding to different intervening variables (such as customer satisfaction or brand loyalty) becomes observable. Thus, psychological constructs may be investigated by measuring their neural correlates. To date, non-observed influences of the effect and interplay between analytic and affective information processing can be analyzed by means of the new methodologies. For instance, in the abovementioned study, Deppe et al. (2005a) investigate the neural mechanism elicited by brands in a fictitious buying decision. In another study Deppe et al. (2005b) analyze the neural correlates of a framing-effect caused by a magazine brand. Both studies provide evidence that brands
can activate different “pathways” (Kosslyn, 1999) in the brain. Moreover, these results confirm with the understanding of the brand loyalty-concept (Chaudhuri and Holbrook, 2001; de Chernatony et al., 2004) and can help in the development of new models for marketing management, for instance, regarding brand equity measurement.

However, marketing researchers often find the literature on neuroimaging somewhat overwhelming and confusing (Rossiter et al., 2001b). For instance, “googling” the term neuromarketing currently yields more than 155,000 hits. Even searching the PsychInf-Database for one specific brain region such as the “striatum” delivers nearly 4,000 peer-reviewed articles. In the marketing literature, an overview is clearly needed, just as other researchers have provided in the economic literature (Camerer et al., 2004; Glimcher and Rustichini, 2004; Zak, 2004; Fehr and Singer, 2005; Kenning and Plassmann, 2005). In this context, the purpose of the present paper is to provide such an overview through applying tried and tested measurement methods from modern neuroscience to marketing research and considering their advantages and disadvantages. Because understanding fMRI is crucial to its application in marketing research, this paper aims to advance the knowledge of fMRI in the field of marketing.

The paper is structured as follows. The first section reviews several neuroimaging techniques and the conclusion is drawn that the method of functional magnetic resonance imaging is currently the most promising approach to answering fundamental marketing research questions. Consequently, we then focus on fMRI and methodological issues in fMRI experiments and data analysis are explained in the second part of the paper. Additionally, there is a short overview of the first studies in consumer neuropsychology which use neuroimaging techniques. The final section considers some preliminary implications for marketing theory and management.

 Oversight of current neuroimaging techniques
Current neuroimaging techniques can be grouped roughly into two main categories (Table I) according to the underlying mechanisms measured (Huesing et al., 2006). These categories are procedures for measuring electrical activity of the brain and those for measuring neural metabolism processes (for an overview, see Kandel et al., 2000).

Electromagnetic recordings
Electroencephalography (EEG). EEG measures voltage fluctuations on the scalp (Hansen, 1981; Klebba, 1985; Rossiter et al., 2001a). The underlying ion currents occur rather remotely from the electrodes (across skin and skull) in cortex areas near the surface and result from changes in membrane conductivity elicited by synaptic activity and intrinsic membrane processes (da Silva, 2004). An electrode on the skin virtually “sees” the summed potentials generated by a large number of neurons.

With a temporal resolution of milliseconds and lower, EEG can easily detect the time course of neuronal activity, but spatial resolution remains limited because of the so-called inverse problem (Helmholtz, 1853). Because an infinite number of source configurations can generate identical potentials on the skin, estimated solutions of the inverse problem, i.e. source localization, require appropriate a priori assumptions about sources and volume conduction in order to yield physiologically meaningful data (Babiloni et al., 2005; Michel et al., 2004).

Magnetoencephalography (MEG). MEG is sensitive to changes in magnetic fields that are induced by electrical brain activity. The temporal resolution can be compared to that of the EEG, so that this modality can, for example, resolve the temporal...
sequence of different cortical activities involved in decision-making (Braeutigam *et al.*, 2001). However, in contrast to the EEG, MEG is also able to depict activity in deeper brain structures (Ambler *et al.*, 2004). The inverse problem applies essentially to MEG as well, so that source localization is equally dependant on valid assumptions. Integrating the different brain imaging techniques could further improve current models of source localization (da Silva, 2004).

**Methods measuring metabolic or hemodynamic responses to neural activity**

**Positron emission tomography (PET).** Positrons, the antiparticles of electrons, are emitted by certain radio-nuclides. These nuclides have the same chemical properties as their non-radioactive isotopes and can replace the latter in biologically relevant molecules. After injection or inhalation of tiny amounts of these modified molecules, for example, modified glucose or neurotransmitters and their spatial distribution can be detected by a PET-scanner. This device is sensitive to radiation resulting from the annihilation of emitted positrons when they collide with ubiquitously present electrons. From the detected distribution, information on metabolism or brain perfusion can be derived and visualized in tomograms. Spatial resolution is quite high (about 3-6 mm), but temporal resolution is low (several minutes to fractions of an hour).
Because radioactive tracers are used, the application to healthy test persons is restricted.

**Functional magnetic resonance tomography (fMRI).** FMRI is currently the most frequently used functional brain imaging technique (Huesing et al., 2006). Magnetic resonance scanners produce sets of cross sections – tomograms – of the brain, exploiting weak, but measurable resonance signals that are emitted by tissue water in a very strong magnetic field after excitation by high frequency electromagnetic pulses. The acquired resonance signals can be attributed to their respective spatial origin, and cross sectional images can be calculated. The signal intensity, coded as the gray value of a picture element, depends on water content and certain magnetic properties of the local tissue. In general, structural MR imaging is used to depict brain morphology with good contrast and high resolution.

The ability to visualize brain functions using MRI, depends on the fact that increased neuronal activity of a brain region is followed by a change in the regional cerebral blood flow (Frackowiak et al., 2004). Although the mechanisms of this so-called neurovascular coupling are still not fully understood, the increased perfusion of activated brain tissue is the basis of the Blood Oxygenation Level Dependent (BOLD)-Effect (Kwong et al., 1992): hemoglobin. This is the oxygen-carrying molecule in blood, which has different magnetic properties depending on its oxygenation state. While oxy-hemoglobin is diamagnetic, deoxy-hemoglobin is paramagnetic, i.e. it distorts the magnetic field locally, leading to a local signal loss. In activated brain tissue, the increased oxygen consumption is overcompensated by the blood-flow response. Thus, during activation, deoxy-hemoglobin is replaced partly by oxy-hemoglobin, leading to less distortion of the local magnetic field, that is, to increased signal intensity.

The temporal and spatial resolution of fMRI depends on scanning technology on the one hand and on the underlying physiology of the detected signal intensity changes on the other hand. With current scanner technology, structural images are usually obtained with a resolution of about 1x1x1 mm voxels (the equivalent of a pixel (picture element) in a volume), while fMRI voxels typically have edge lengths of about 3-5 mm. A typical value for the spatial resolution of fMRI is therefore about 3 mm³ (Huesing et al., 2006). As a rule, the temporal resolution of fMRI is between 1 and 3 seconds. For evaluation purposes, it is necessary to take into account that the cerebral blood flow (“CBF”) response to brain activation is delayed by 3-6 seconds.

The clear advantage of fMRI results firstly from a balance between temporal and spatial resolution, allowing whole brain scans in less than three seconds. The second advantage derives from its non-invasiveness, permitting repeated measurements in healthy volunteers ad libitum. In addition, the choice of scanning parameters allows increasing one parameter at the expense of the other. Recent fMRI approaches show that for some neuronal systems, the temporal resolution can be improved down to the level of 100-250 milliseconds (Ogawa et al., 2000, Huesing et al., 2006), and spatial resolution increased to the level of cortical columns as basic functional units of the cortex (Kim and Duong, 2002).

In the preceding discussion, all neuroimaging techniques currently available, have been shown to have both advantages and disadvantages. While the where of brain activity is more easily assessed by fMRI or PET, the question of when – such as the discrimination between parallel and sequential processing – can be answered more
precisely by EEG or MEG. Therefore, in some cases, a combination of methods might be useful but are still rare (Kosslyn, 1999). In this context, it is important that market researcher keep in mind, that various research issues are still in their infancy and basic research is necessary to facilitate an application of these techniques to marketing. Although taking into account that approximately 50 percent of all neuroimaging studies are conducted with the use of fMRI (Huesing et al., 2006) this specific method may also provide an appropriate instrument for market researchers. Against this background, we focus in the following on fMRI. Its methodological foundations are described briefly in the next section (for details, in particular, about the physical foundations, see Frackowiak et al., 2004; Huettel et al., 2004; some helpful advice and caveats are given by Savoy, 2005).

Methodological issues relating to fMRI data analysis

Experimental procedure and data acquisition
The procedure of a typical fMRI experiment can be described as follows: during the experiment, a test person is asked to lie in an MRI scanner for 60-90 minutes without moving. The first 6-15 minutes of an experimental session usually consist of several anatomical/structural scans of the brain. Once the scans have been performed, functional data are collected in a series of “runs” of between 3 and 10 minutes each. During each run, the participant performs whatever tasks the experimenter has designed. Often, visual stimuli are projected onto a screen in front of the participant who can make responses by pressing different buttons. While the task is being performed, the MRI scanner records the so-called blood oxygen level depending (“BOLD”) signal, throughout the brain every couple of seconds. These images are then analyzed in order to identify brain areas that are significantly more or less active during the specified experimental condition, in comparison to the control condition. Different types of experimental design can be identified, such as a blocked or event-related design (Friston, 2004). During a typical fMRI experiment, several functional images are recorded. Each image is divided into a large number of voxels. The data from a single voxel over the course of the fMRI experiment constitutes a time series of BOLD signals which is recorded by the scanner.

Data analysis
Various different software packages are available which can help to analyze the data from the scanning-procedure. Many researchers use “Statistical Parametric Mapping” (SPM), freeware from the Wellcome Department of Cognitive Neurology, London, UK. This software package is referred to below. When using SPM, the analysis of fMRI Data comprises three initial steps: pre-processing, model fitting and statistical inference (Figure 1).

Pre-processing
In order to pre-process the fMRI data, four different steps can be identified (Friston et al., 1995). Firstly, given the fact that different slices within a single brain image are collected sequentially rather than at exactly the same point in time, a temporal adaptation called slice timing must be performed. Secondly, if a participant moves during an fMRI experiment, the brain area to which a specific voxel corresponds, will change. Therefore, a movement correction is executed, a process referred to as
realignment. Thirdly, the brains of different individuals obviously differ in size and shape. If the results from different participants are to be combined, it is necessary to transform the data into a standard “template brain” a process called normalization. Fourthly, the last pre-processing step is spatial smoothing. Essentially, functional brain images are blurred slightly by convolving them with a Gaussian kernel. Therefore, during the smoothing procedure, the value of each voxel is replaced with a weighted average of its value and those of surrounding voxels.

**Model fitting**

Once the data have been pre-processed, each voxel is analyzed individually in an attempt to find voxels whose time series correlate significantly with the experimental conditions. The standard approach is to fit a general linear model (“GLM”) to each voxel’s time series (Frackowiak et al., 2004). This model explains the response variable $Y_j$ (i.e. the hemodynamic response function at a particular voxel) in terms of a linear combination of the explanatory variables plus an error term (equation (1))

$$ Y_j = x_{jl} \beta_1 + \cdots + x_{jl} \beta_L + x_{jL} \beta_L + \epsilon_j $$

Here $\beta_l$ is the unknown parameter, corresponding to each of the $L$ explanatory variables $x_{jl}$ (where $l = 1, \ldots, L$). The errors $\epsilon_j$ are independent. Writing equation (1) in full, for each observation $j$, yields the following set of simultaneous equations:

**Source:** Frackowiak et al. (2004)
This has the equivalent matrix form:

\[
\begin{pmatrix}
Y_1 \\
\vdots \\
Y_j \\
\vdots \\
Y_J
\end{pmatrix} =
\begin{pmatrix}
x_{11} & \cdots & x_{1l} & \cdots & x_{1L} \\
\vdots & \ddots & \vdots & \ddots & \vdots \\
x_{j1} & \cdots & x_{jl} & \cdots & x_{jL} \\
\vdots & \ddots & \vdots & \ddots & \vdots \\
x_{J1} & \cdots & x_{Jl} & \cdots & x_{JL}
\end{pmatrix}
\begin{pmatrix}
\beta_1 \\
\vdots \\
\beta_j \\
\vdots \\
\beta_J
\end{pmatrix} +
\begin{pmatrix}
\varepsilon_1 \\
\vdots \\
\varepsilon_j \\
\vdots \\
\varepsilon_J
\end{pmatrix}
\]  

(3)

and can be written in matrix notation as follows:

\[
Y = X\beta + \varepsilon
\]

(4)

where \( Y \) is the column vector of observations, \( \varepsilon \) the column vector of error terms, and \( \beta \) the column vector of parameters.

The \( J \times L \) matrix \( X \) with the \( jl \)th element \( x_{jl} \) is the design matrix. For instance, this matrix can be utilized to specify the covariates corresponding to the different conditions in the experiment. For example, if the participant has repeatedly alternated between ten scans of the experimental condition, and ten of the control condition, the model might include a covariate with the value 1 for each scan, corresponding to the experimental condition, and the value 0 for each scan corresponding to the control condition. After the design matrix has been defined, the different parameters are estimated, based on the GLM. Therefore, a method of estimating parameters that “best fit” the data, is required. The least square estimates applied by SPM Version 2 are restricted maximum likelihood estimates.

**Statistical inference**

The regression coefficients associated with each covariate in the best fit are called the \( \beta \)-values (equations (1)-(4)) and they are used to compute the statistical values (e.g. \( t \)-values) associated with each voxel for a given contrast of covariates. Different contrasts can be analyzed in terms of the experimental design and research questions. Once statistics have been computed for each voxel, they can be displayed together in a statistical parametric map, which is simply a brain image in which the value of each voxel is its corresponding statistic. These maps can then be “thresholded” and overlayed onto structural images in order to graphically display which areas of the brain exhibit activity that passes the desired threshold of statistical significance. Often, different color schemes are used to aid visualization (e.g. red for \( t \)-values above 3.5, yellow for \( t \)-values above 5.0, etc.).

**Data interpretation**

The fact that certain brain functions like speech or vision are processed in dedicated brain areas, has been common knowledge for quite some time. Even before the emergence of
non-invasive neuroimaging techniques, patients with brain lesions caused by trauma or disease were studied. Since then, it has been known that, for instance, the destruction of parts of the occipital lobe leads to cortical blindness, and aphasia may be a consequence of lesions in the temporal (Wernicke’s area) or frontal lobe (Broca’s area). More complex functional losses result from lesions of the ventromedial prefrontal cortex, as in the well-known case of Phineas Gage. When this part of his frontal lobe was destroyed in an accident in 1848, Gage’s personality and social behavior were severely altered, whereas his intellectual capabilities remained largely intact (Steegmann, 1962, p. 952). Experiments with intra-operative direct-brain stimulation constitute an example of other historic sources of knowledge about localizing brain functions (Penfield and Boldrey, 1937).

After the statistical analysis on a single subject level has been concluded, SPM facilitates various group analyses which generalize the results to the underlying population (Frackowiak et al., 2004).

**Comparing brains for group analysis**

When neuropsychological studies collect data from groups of individuals, certain steps must be taken to enable data analysis across these groups of individuals. Like fingerprints, no two brains are identical. In order to compare activations across individual subjects, the various brains are usually spatially normalized to a template brain. That is, they are transformed so that they are similar in overall size and spatial orientation. Generally, the aim of this transformation is to bring homologous brain areas into the closest possible alignment.

The Talairach stereotactic coordinate system is used for this purpose. Talairach and Tournoux (1988) introduced three important innovations: a coordinate system to identify a particular brain location relative to anatomical landmarks; a spatial transformation to match one brain to another; and an atlas describing a standard brain with anatomical and cytoarchitectonic labels. The coordinate system is based on identifying the line connecting the anterior commissure (AC) and posterior commissure (PC) – two relatively invariant fibre bundles connecting the two hemispheres (Figure 2). This AC-PC line defines the $y$-axis of the brain coordinate system. The origin is set at the AC. The $z$-axis is orthogonal to the AC-PC-line in a foot-head direction and passes through the interhemispheric fissure. The $x$-axis is orthogonal to both other axes and points from AC to the right. Any point in the brain can be identified relative to these axes, which define the Talairach coordinate system.

Most analysis software such as SPM currently use templates created by the Montreal Neurological Institute (MNI), based on the average of many normal MR scans. Although similar, the Talairach and the MNI templates are not identical, so care must be taken when comparing activation maps from several different studies. A detailed description of this issue can, for example, be found in Brett et al. (2002).

**Preliminary results of initial studies**

To date, only a few papers have been published in scientific literature which explicitly address consumer research issues with the use of fMRI. The following Table II provides an overview of these studies.

When reviewing those studies, one find at first that some of them report that consumers use particular decision strategies or processes, or say “pathways” due to the stimuli available, the context and their emotional state. For instance, nearly all
neuroimaging studies on brand decision processes reveal that a brand logo triggers brain activity in areas which are crucial for integrating emotions and self-reward (Erk et al., 2002; McClure et al., 2004; Deppe et al., 2005a; Deppe et al., 2005b). This result implies that in marketing research, decision processes should be subjected to a more differential and careful analysis in respect to the concept of emotions.

However, until now, all these studies have been explorative and do not refer in extenso to another. Nevertheless, by reviewing these studies, one can identify some brain structures which might be crucial not only but also for marketing researchers:

- According to a study by Deppe et al. (2005b), we know that certain emotionally-associated brain areas correspond to brand preferences, i.e. the medial prefrontal cortex and partly the posterior cingulate. Furthermore, from studies in neuroscience and neuroeconomics, there is evidence that some parts of the prefrontal cortex, especially the ventromedial prefrontal cortex (VMPFC), play a key role during emotional processing in (economic) decision making (Kenning and Plassmann, 2005). In this context, the prefrontal cortex seems to function as a hub in the control system (Ridderinkhof et al., 2004; Paulus and Frank, 2003). Additionally in the above mentioned study, Ambler et al. (2000) report activity changes in the anterior and posterior cingulate cortex (ACC and PCC) due to processing of affect-related stimuli.

- The neuroscientific literature provides evidence that the increased activity of brain structures associated with the human reward system correlates with subjects’ descriptions in context of “pleasant” “liking” or “desirable” items. Positive descriptions of somatic states induced by, for example consumption of consumer goods, like “pleasant” or “attractive” could potentially also be correlated with changes in the neuronal activity of these brain structures. However, until now, only a few consumer neuropsychology studies have investigated the role of the rewarding system for marketing-related issues. These studies are Deppe et al. (2005a), Erk et al. (2002), McClure et al. (2004), Plassmann et al. (2006a, b) and Schaefer et al. (2006).
<table>
<thead>
<tr>
<th>Author</th>
<th>Field</th>
<th>Question</th>
<th>Results</th>
</tr>
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<tbody>
<tr>
<td>Erk et al. (2002)</td>
<td>Decisions between different products (automobile), fMRI</td>
<td>Is it possible to find neural correlates to evaluate the attractiveness of a product?</td>
<td>Products which symbolize wealth and status lead to a higher activity in areas which are responsible for rewards In a decision-making process, favorite brands reduce analytic processing and lead to increasing attractiveness in fields associated with rewards</td>
</tr>
<tr>
<td>Deppe et al. (2005a)</td>
<td>Choice between different brands, fMRI</td>
<td>Which neural correlates form the basis of brand choice?</td>
<td>In situations of doubtful credibility, brand information has an important influence on the decision-making process which results in higher attractiveness in fields which include rewards in decision making</td>
</tr>
<tr>
<td>Deppe et al. (2005b)</td>
<td>Influence of brands on credibility judgments, fMRI</td>
<td>Which neural correlates form the basis of brand information as a frame in decision processes connected?</td>
<td>In situations of doubtful credibility, brand information has an important influence on the decision-making process which results in higher attractiveness in fields which include rewards in decision making</td>
</tr>
<tr>
<td>McClure et al. (2004)</td>
<td>Choice between different brand products and their flavour perception, fMRI</td>
<td>How does brand information influence the flavour perception of sensorily similar products?</td>
<td>Depending on the brand information given to the test person, different areas are activated by the consumption of a soft drink. If the consumer believes the drink to be his favorite brand, areas of rewards are activated</td>
</tr>
<tr>
<td>Klu-charev et al. (2005)</td>
<td>Advertising effect of Celebrities, fMRI</td>
<td>How does the so-called “Expertise Hook“ influence recollection?</td>
<td>The presumed expertise of celebrities leads to an increased activation in memory structure and a significant positive influence on purchase intention</td>
</tr>
<tr>
<td>Plass-mann et al. (2006a)</td>
<td>Choice between different service brands, fMRI</td>
<td>How do information asymmetries influence the neural “favorite brand-effect”?</td>
<td>The favorite brand-effect of an anterior study (Deppe et al., 2005a) could be replicated for decisions under uncertainty. In particular, with uncertain decisions, the favorite brand leads to activation of areas responsible for the integration of rewards into decision making</td>
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Table II. Overview of fMRI studies related to marketing issues
<table>
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<tr>
<th>Author</th>
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<th>Results</th>
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<tbody>
<tr>
<td>Plassmann et al.</td>
<td>Choice between different store brands by loyal and disloyal customers, fMRI</td>
<td>What is the neural mechanism behind brand loyalty?</td>
<td>Loyal retail store customers show significant neural activations in brain areas involved in reward processing when their preferred store brand is for choice as compared to disloyal customers.</td>
</tr>
<tr>
<td>Schaefer et al. (2006)</td>
<td>Choice between different car brands, fMRI</td>
<td>The aim of this study was to examine the neural correlates of culturally-based brands</td>
<td>Results showed activation of a single region in the medial prefrontal cortex related to the logos of the culturally familiar brands. The authors interpreted the results as self-relevant processing induced by the imagined use of cars with familiar brands and suggest that the prefrontal cortex plays a crucial role for processing culturally-based brands.</td>
</tr>
<tr>
<td>Yoon et al. (2006)</td>
<td>Choice between different brands</td>
<td>Are there parallels between human personalities and brand “personalities”?</td>
<td>Brand personalities and human personalities are processed differently in the brain. Brand personalities are processed in areas of object recognition and human personalities in areas, which are responsible for integrating of rewards in decision making.</td>
</tr>
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</table>
Limitations of fMRI

Although the use of fMRI in market research is seemingly a promising approach, this synergistic research also faces several limitations.

Firstly, as with most brain imaging techniques, fMRI allows rather simple designs, compared to traditional experimental designs in marketing research. For example, fMRI relies on many stimulus presentation repetitions in order to reduce the noise in the fMRI signal by averaging across a large number of trials.

Secondly, the medical environment limits the perceived richness of real-world marketing stimuli. For example, all mentioned neuroscientific techniques have difficulties in handling a subject’s body movements such as head movements in response to a stimulus.

Thirdly, the complexity of the underlying neurophysiological processes necessitates a deep understanding of the specific neuroscientific technique in order to correctly test a suggested hypothesis. One crucial requirement, for example, is the correct specification of the various control conditions.

Fourthly, with respect to the ethical effects of this integrative research, there is the danger that the public might ignore the neurobiological and technical restrictions and treat initial results as the indisputable truth. Thus, the publication and critical discussion of results is crucial to avoid possible misuse of brain-imaging techniques in advertising research.

Fifthly, brain-imaging techniques such as fMRI require both sophisticated and expensive hard- and software-tools. For example, a typical 1.5 Tesla MRI scanner costs between 1 and 2 million € (Huesing et al., 2006). For some specific materials (e.g. helium for the scanner, specific rooms, high-end work stations) the annual expenses are approximately 100,000-200,000 Euros. Thus, the costs of scanning one subject per hour are estimated to be in the range of 300-400 € (Huesing et al., 2006).

Finally, the interpretation of neuroimaging data is much more complex than that of behavioral data or information derived from questionnaires (Kosslyn, 1999). Not only the nature of the task itself, but also the relationship between performance and the underlying physiology are sources of concern and relatively new issues for market researchers.

Outline – theoretical and practical implications

As a result of these limitations, for the next few years, functional brain imaging technologies will not be available to marketers for routine market studies such as packaging and product-development research, but important key areas can already be explored theoretically. From the practitioner perspective, three relevant areas can be highlighted.

Firstly, marketing managers often find themselves in situations in which they must make decisions about different advertising concepts. Such decisions might be to determine which story board for a commercial is more appealing, or which individual sequence of a commercial should be included in the final TV spot. Depending on the specifically targeted advertising message, fMRI can be used to compare the neural correlates of different video sequences in the consumer’s brain and how this contributes to the brand equity stored in the brain of the consumer.

Secondly, apart from the advertising content, the marketing manager must decide on the advertising environment. An important issue, for example, is whether, in order
to increase advertising effectiveness, an advertisement should be printed in Magazine A rather than in Magazine B. A recent study by Deppe et al. (2005b) demonstrated the neural correlates of subconscious framing effects on credibility judgments of news headlines induced by different magazine brands (Deppe et al., 2005b). Thus, with the help of fMRI, the prevailing perception of the media frame and its impact on the advertisement could be investigated. With this market research might get a feeling for the interplay between different brands.

Thirdly, for some products, price knowledge could be assumed to become an automatic process which is typically hard to articulate, as price-decisions may be unconscious (Sanfey and Cohen, 2004). Or, as Bechara and Damasio (2005) point out: “Thus, knowledge without emotional signaling leads to the dissociation between what one knows or says and how one decides to act” for example at the point of sale. Therefore, as a function of purchase frequency, explicit price knowledge might have an inverted U-shape. It is low for both products whose prices we really do not know, and for those whose prices we know only by intuition or gut feeling. Between these two extremes, it is high. Neuroimaging studies conducted by marketing researchers may provide some insight into this hypothesis by investigating the neural correlates of price knowledge (Evanschitzky et al., 2004).

However, is there really a need for such a complicated methodology? Why not simply use EDR or eye-trackers, for example, to investigate such problems, given that these methods are considerably less complicated? Metaphorically speaking, measuring complex brain activity with a method which records just one signal, may be compared to an attempt to depict the music of an orchestra by measuring only the noise level. Although possible, information that is crucial to the task at hand will surely be lost. Thus, depending on the specific research question, a mix of different methods should ideally be applied.

Conclusion
In conclusion, initial studies show that a reliable and valid application of functional brain imaging techniques to consumer research questions is possible (Ambler et al., 2004). In particular, the initial fMRI studies in the field seem promising (Erk et al., 2002; McClure et al., 2004; Deppe et al., 2005a). The next step will be to overcome this explorative phase and to conduct much more theoretically guided marketing-related studies. However, in order to determine, whether for market researchers, fMRI or other techniques such as MEG really provide a “window into the consumer’s mind” much more empirical evidence is needed. It was one aim of this paper to enable the reader to conduct research in this area.

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