The Feasibility of Neuroimaging Methods in Marketing Research

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On July 17, 1990, President George Bush issued "Proclamation #6158" which boldly declared the following ten years would be called the "Decade of the Brain" (Bush, 1990). Accordingly, the research mandates of all US federal biomedical institutions worldwide were redirected towards the study of the brain in general and cognitive neuroscience specifically. In 2008, one of the greatest legacies of this "Decade of the Brain" is the impressive array of techniques that can be used to study cortical activity. We now stand at a juncture where cognitive function can be mapped in the time, space and frequency domains, as and when such activity occurs. These advanced techniques have led to discoveries in many fields of research and clinical science, including psychology and psychiatry. Unfortunately, neuroscientific techniques have yet to be enthusiastically adopted by the social sciences. Market researchers, as specialized social scientists, have an unparalleled opportunity to adopt cognitive neuroscientific techniques and significantly redefine the field and possibly even cause substantial dislocations in business models. Following from this is a significant opportunity for more commercially-oriented researchers to employ such techniques in their own offerings.

The redefinition of market research to incorporate such techniques will see the further evolution of "neuromarketing" – the research of the cognitive responses and consequent behaviour to marketing techniques, elements and modalities mediated by a specific cortical response. Nevertheless, it is important to bear in mind that, like cognitive neuroscience itself, market research is constantly

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evolving. In light of this symbiotic development, application of brain imaging to investigate intuitively appealing, but scientifically simplistic – and ultimately meaningless – concepts like the "buy button" in the brain cannot be the sole remit of neuromarketing (Senior and Lee, 2008; Lee et al, 2007). This is despite what appears to be the common perception in recent popular press articles that neuroscientific techniques will enable marketers to essentially 'control consumers' (e.g. The Economist, December 20, 2008). Unfortunately, this myth is perpetuated by publications aimed at the interested consumer and business person: for example, the subtitle of a recent book on neuromarketing is "Understanding the Buy Buttons in Your Customer's Brain". Similarly, in his bestselling book *Buy.ology*, Martin Lindstrom argues that he shows how marketers are able to apply advances in neuroscience to control consumer perceptions, emotions, and behaviours. Yet this is the same claim made by Vance Packard in *The Hidden Persuaders* over 50 years ago about advertising. Such fanciful claims are likely to be just as dubious now as they were then. Of course, it is unarguable that incorporating cognitive neuroscience theory will help both marketing academics and practitioners to move away from traditional market research methods fraught with systemic limitations and biases. This movement will certainly be towards a greater ability to understand why and/or how consumers make the decisions they do, and also towards research in marketing which has implications for understanding more general organizational and social behaviour (Lieberman, 2005) in a marketing-relevant context. Yet the fantastical notion of controlling consumer behaviour is no closer now than it was in 1957 when Packard argued that subliminal advertising could influence your behaviour without you knowing it (Senior and Lee, 2008).

Nevertheless, the evolution of neuromarketing has already begun and, as is the case with any fledgling science, heated debate is regularly seen in the literature. One recent example, in the prestigious pages of the ultra high-impact journal *Nature Neuroscience*, questions the ethics behind neuromarketing and as such is fundamental reading (Nature Neuroscience, 2004; Brammer, 2004). Similar conclusions are drawn in the *Economist*, which recently characterised the potential of

advances in neuroscience applied to marketing as 'sinister' (December 20, 2008, p. 99). Putting ethics aside, the *Nature Neuroscience* editorial highlights some of the key regions of the brain that may be implicated in consumer preferences. For example, one study cited (which will be covered in more depth presently) revealed differential activity in the brain areas that mediate reward processing when the participants tasted different colas (either Coca-Cola or Pepsi-Cola). Furthermore, when these respondents were told that the drink they had just imbibed was Coca-Cola compared to its brand rival, Pepsi-Cola, a wider network of brain reward areas was activated. This was interpreted as indicating that Coca-Cola had a more efficient advertising campaign (McClure et al, 2004). Another study examined the possible marketability of different types of cars and found that respondents who rated sports cars as being attractive engendered more activity in these brain reward areas when they were shown such cars compared to other vehicles (Erk et al, 2002). Attractive human faces also enjoy such privileged status and activate the brain reward areas more so than unattractive faces. Our own experience tells us that attractive faces are effective drivers of behavior, and therefore they are ideal mechanisms to initiate consumer behavior (Senior, 2003). Given that emblems such as facial beauty or a particular brand of cola can activate these "pleasure centers" and drive social behaviour, their study is thus one possible valid enterprise for neuromarketing research. Yet it is important to note that the results of such investigation are never self-evident simply from the data. As we can see from the above examples, these results need interpretation in light of relevant theory. For example *why* was Coca-Cola associated with a wider network of brain reward areas? McClure et al. (2004) interpreted this in light of a (somewhat superficial it must be said) understanding of advertising theory, but there are almost always competing explanations. Thus any researcher – commercial or academic – who enters such waters must have the theoretical tools with which to interpret results (as well as to design effective programmes of research).

In a market research context, an understanding of the brain reward system looks likely to be the crucial theoretical crutch in the first instance. These "brain reward areas" are parts of the same

cortical network that people addicted to drugs stimulate with their drug of choice, and animal studies have shown that female rats will ignore their pups to self-administer electrical stimulation to these areas until they die of exhaustion (Valenstein and Beer, 1964; Routtenberg and Lindy, 1965). Knowing that such appetitive behavior is mediated by a specific network of brain areas, that are also active for perception of a particular product brand (as was seen in the cola study above), can provide insight into factors influencing consumer behaviour. Taking in hand the obvious limitations behind such neuroreductionist reasoning, knowledge of the areas in a consumer's brain that are activated when they are shown a particular product can be a much more "honest" indicator of their cognition compared with other traditional measures such as focus groups or questionnaires where responses can be biased (Wolpe et al, 2005). Thus, before any discussion of the specific neuroimaging techniques available to the researcher, it is important to identify further the neuroanatomy of the key regions of this reward system.

THE BRAIN REWARD SYSTEM

A central component of the human motivational systems is the amygdala which is an umbrella term for a functionally and anatomically heterogeneous collection of nuclei that reside in the superiomedial (situated above and at/or toward the midline) aspect of the anterior temporal lobes. The dense reciprocal interconnections that convey information to and from a wide variety of neural areas ensure that the amygdala (or amygdaloid complex) is well situated to play an important role in the computations that underpin the perception of reward within market exchanges.

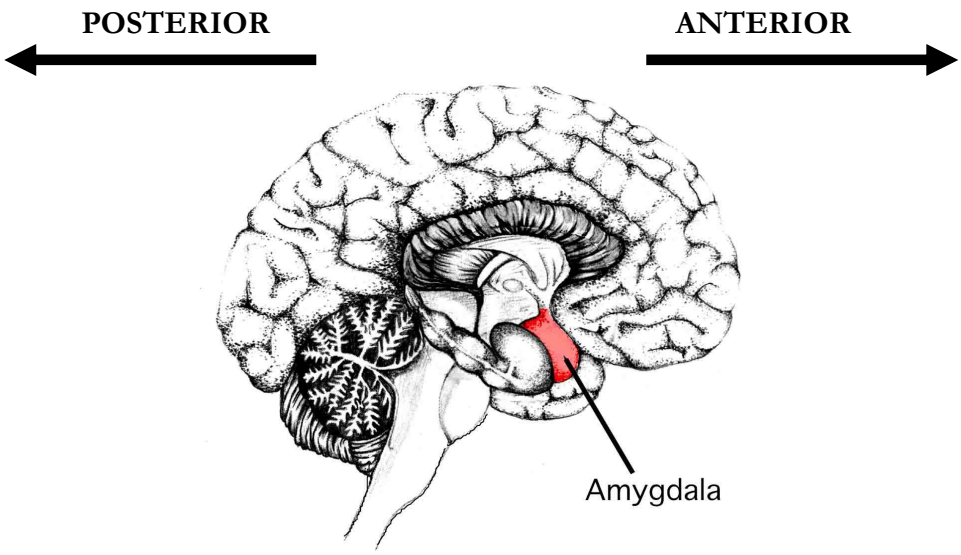

Figure 1: Sagital view of the human brain with the position of the amygdala highlighted. Adapted from http://thesituationist.wordpress.com/

The various nuclei that constitute the amygdala are defined according to the particular functional criteria adopted, but it is generally agreed that there are two main clusters, these being the, older and smaller, corticomedial group and the basolateral group (Aggleton, 2000). Visual input with an affective component, as would be the case with an advertisement, is projected from the occipital cortex to the ventral basolateral nuclei of the amygdala which in turn projects to the dorsal corticomedial group for the initial stages of appetitive reward (Aggleton and Young, 2003)

The sublenticular (below the lentiform body) extended amygdala of the basal forebrain projects from the corticomedial group into the stria terminalis to form an extension of the "core amygdala." The stria terminalis project into the caudate body and to the nucleus accumbens. Due to the relay nature of the amygdala, the nucleus accumbens thus enjoys reciprocal connectivity between the insular cortex, the hippocampal formation, and the medial prefrontal cortex (Heimer et al, 1997). Further evidence showing projections from the corticomedial group to the dopaminergic (i.e. dopamine-based) brain reward areas does suggest that it may play an initial role in perception of

rewarding stimuli such as perception of attractive faces etc (Senior, 2003) with the brain reward system being "activated" at subsequent stages (Fudge and Haber, 2000).

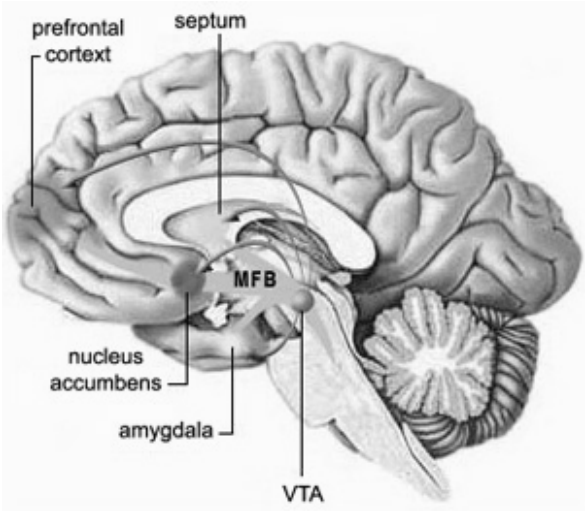

Figure 2: Overview of the main projections from the amygdala via the medial forebrain bundle (MFB) to the ventral tegmentum (VTA),prefrontal cortex and nucleus accumbens .source:http://elementy.ru/.

The areas of the brain that mediate reward are diverse but are linked together through the medial forebrain bundle (MFB) — a complex structure consisting of approximately 60 fibre bundles that project through the lateral hypothalamus toward the rostral basal forebrain. The ventral tegmentum (VTA) is a dopaminergic site that is connected by a descending component of the medial forebrain bundle. The ventral tegmentum also projects to other areas of the brain, such as the nucleus accumbens and the orbitofrontal gyrus, which as noted above are seen to play a role in the anticipation of a rewarding stimulus (Rolls, 2000). These systems are likely to have evolved to ensure the appetitive drive toward stimuli that were beneficial to our survival as a species. In light of such an adaptive value it makes sense to examine their role during the perception of market exchanges, as it would then highlight any overlap that such exchanges have with our general social behaviour. From a commercial standpoint, the successful market researcher would need clear knowledge of

such brain systems to identify the ideal technique to employ from the two main brain imaging techniques, functional magnetic resonance imaging (fMRI) and magnetoencephalography (MEG). Both tools are described next, prior to a selection of case studies that serve to highlight the types of questions that can best be answered by each of these techniques.

FUNCTIONAL MAGNETIC RESONANCE IMAGING (fMRI)

While MRI technology has been in use for much of the last half-century (particularly in a medical context) its use to examine brain function, or fMRI, is just over a decade old. Yet despite this, it is now undoubtedly the most prolific of all brain imaging techniques. Merely entering "fMRI" as a search term into the journal article search engine, www.pubmed.com, will return over 13,000 items compared to a mere 2,000 returned for "MEG." The utility of fMRI is mediated by one key factor – it is relatively easy to implement. It is a completely non-invasive procedure where the volunteer is simply moved into the centre of a high-field circular magnet bore. Various experimental stimuli, such as advertisements for particular products, can then be projected into the centre of the bore, which the subject views via a small prism mirror placed just above the face. A variety of neurophysiological information can be obtained using fMRI. For example, baseline cerebral blood volume measurements, changes in this blood volume, quantitative changes in the levels of blood oxygenation, as well as the rate of resting state oxygen extraction. More detailed descriptions of each of these measures is provided in Russell et al. (2003), but one measure that will have great utility for the neuromarket researcher is the "BOLD" contrast.

The "BOLD" in "BOLD" contrast stands for Blood Oxygen Level Dependant (Tank et al, 1992). In brief, this signal is driven by a difference in the blood oxygenation levels in capillaries and veins as compared to in the arteries during a particular task. Deoxygenated blood is paramagnetic (attracted to a magnetic field), as opposed to when it is oxygenated (Pauling and Coryell, 1936). While we are not exactly sure why, we do know that on presentation of a specific stimulus, oxygenated blood flow

will increase locally within an "active" region of the brain. This will cause deoxygenated blood levels to decrease and subsequently decrease the magnitude of the magnetic field distortions between the deoxy- and oxyhemoglobin which ultimately leads to a signal increase in the fMRI dataset (Ogawa et al, 1992). The main limitation of this technique is that the signal begins to increase approximately two seconds after stimulus presentation, and reaches a plateau after about seven to ten seconds (Logothetis et al, 2001). To use more exact terminology, fMRI has excellent *spatial* resolution but relatively poor *temporal* resolution, i.e. it can be used to detect activity in specific and, in some cases, quite small regions of the brain but it can tell you less about the timing of that activity. This has significant implications for the type of information fMRI can provide, in particular making it very suitable for the identification of certain brain areas. However, the exact maximum possible resolution is a product of several factors, including the individual laboratory, so it is difficult to give an exact figure for spatial resolution.

The functional activity revealed with the BOLD contrast then needs to be mapped on to a picture of the subject's brain. To create a neuroanatomical picture the MRI procedure utilises the behaviour of protons when exposed to a magnetic field. In short, in their natural state protons are aligned randomly thoroughout the body. However, an applied magnetic field causes then to align along it, a rapid radiofrequency pulse is then applied which forces the hydrogen protons to tilt away from their magnetic alignment. When the radiofrequency pulse is switched off, these protons relax and return to their original alignment with the magnetic field emitted by the MRI scanner. The different rates of proton relaxation across the various structures of the brain allow an image to be constructed (Russell et al, 2003). While the non-invasiveness of fMRI is attractive, the rapid switching of the radiofrequency pulse required for the neuroanatomical MR image is rather loud and can cause permanent hearing loss in some cases, so most laboratories require subjects to wear ear protection during a scan. This, coupled with the fact that subjects are positioned inside the centre of a very large superconducting magnet, the inner surface of which is sometimes just inches away from the

subject's face and body, would suggest that fMRI can be quite a stressful or traumatic procedure to undergo. This unnatural environment could theoretically influence results of any study, and the obvious lack of ecological validity needs to borne in mind when carrying out neuromarket research. Obtaining responses from a subject in a potentially stressful environment is likely to bias any results. However, we have found that experimental subjects, in general, tend to consider fMRI to be a "surprisingly relaxing" experience (Cooke et al, 2007).

MAGNETOENCEPHALOGRAPHY (MEG)

Whilst fMRI is an ideal tool for locating cortical activity, it is of course possible that differences in the timing of that activity may also be of interest. However this type of neurophysiological data is probably better collected using tools which directly and immediately measure the electromagnetic activity of the brain caused by stimuli, rather than an indirect time-delayed physical response as fMRI does. There are a number of tools available for this purpose, including electroencephalography (EEG), steady-state topography (SST), and magnetoencephalography (MEG). EEG and SST are related methods, which rely on recording the electrical signals at the scalp surface. MEG on the other hand measures the magnetic fields generated by the brain's electrical activity, allowing the potential to measure activity throughout the brain. While EEG and SST have utility in a neuromarketing context (as demonstrated by their use along with fMRI in Lindstrom's *Buy.ology*), particularly by way of practicality due to their potential portability, if MEG is feasible it is likely to be able to offer greater detail and insight. Thus MEG will be the focus of the present discussion. Obtaining MEG data is a very different process from fMRI, as it involves the measurement of extremely weak magnetic fields generated by the electrical activity of neuronal populations (Hamalaainen and Hari, 2002). Compared with fMRI, MEG has excellent temporal resolution but relatively poor spatial resolution, i.e. it can detect cortical activity at the millisecond level but it is not as good at distinguishing the space where this activity originated. That said, this is dependent on a number of key factors, in particular the question being asked, and the *a priori* information which is

available, for example whether the general area of the source is already hypothesized/known (e.g. one may know the location should be on the cortex). In such situations, the potential locations of the signal are significantly reduced, allowing a much greater spatial resolution, at times down to a few millimetres, equivalent or even superior to fMRI[1]. While MEG, in general, is less able than MRI to localise activity in deep brain structures such as the amygdala recent work is showing that this is improving[2]. While this has some implications for the questions MEG can help us ask (i.e. it is currently best suited to questions which involve activity at the cortical level), contemporary imaging techniques developed from radar technology do considerably improve on this comparatively poor spatial resolution (Hillebrand et al, 2005). However, given the availability of solid *a priori* theory in allowing MEG to localise activity in a particular region, it can be seen that it is ideally suited to employment in neuromarketing research. More specifically, as has been argued before (see Lee, Broderick and Chamberlain 2007; Senior and Lee 2008), neuromarketing research must be based on strong *a priori* theory if it is to deliver value and become, to some extent, a predictive tool, not conducted in an exploratory and almost hand-waving fashion (as much recent work has been). The use of MEG rather than fMRI in such work is thus likely to influence the development and definition of a stronger theoretical framework for neuromarketing work.

Even so, measuring such minute neural activity is challenging, due to the very weak nature of the magnetic field signal from the neuronal clusters, and also the potential interference from nearby electromagnetic noise. Even noise sources arising from the subject's own body, such as coughing, etc. can have serious implications for the integrity of the data. Nevertheless, as is the case with fMRI scanning, contemporary image analysis software can ensure that most of these artefacts are controlled for or filtered out. During a MEG scan, the subject's head is raised into a "dewar" which houses an array of superconducting sensors called superconducting quantum interference devices (SQUIDS). To collect the optimal signal, it is preferential to use dewars with as large a collection of

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SQUIDS as possible and the current generation of MEG scanners can contain up to 300 separate SQUID detectors (Singh, 2006). The temporal resolution of MEG is close to real time, but its ability to detect the onset of cortical activity is not its only advantage. The use of MEG also allows study of changes in neuronal oscillatory rhythms, i.e. the specific *frequency* at which neurons in a particular cluster fire together (Hillebrand et al, 2005). A specific oscillatory frequency range, e.g. 28-40 Hz, will either increase or decrease during an experimentally salient period of time, such as when participants view a visual stimulus (Singh, 2006). Take for instance the modulation in activity between 28-40Hz that occurs when a subject recognizes a face (Rodriguez et al, 1999). This modulation in task-related oscillatory behavior is sometimes called event related synchronization (ERS) or event related desynchronization (ERD), depending on the direction of the change, i.e. either in the same frequency band or towards a different frequency band respectively (Pfurtscheller, 2001). Whilst still preliminary, there is an emerging body of evidence that certain frequency bands can be identified as signatures for specific cognitive tasks, e.g. 28-40 Hz ERS for object recognition (see above) or 14-28Hz ERS for verbal working memory (Hwang et al, 2005) or even 4-8 Hz ERS for episodic recall (Klimesch et al, 2001). This may provide a further tool for neuromarketer in the understanding of market behavior.

Owing to the sensitive nature of the SQUIDS, it is essential to implement a number of conditions prior to carrying out a MEG procedure. The dewar needs to be isolated in a double magnetically shielded room to ensure that data are not biased by transient electromagnetic fields in the local environment. The fact that the subject's head is held in the MEG dewar may lead to the assumption that it is an uncomfortable procedure. But the subject is actually rather comfortably sitting in a chair as opposed to lying down and the equipment is substantially less claustrophobic than the fMRI machine. However, subjects' responses in our qualitative questionnaire data show that, whilst it is considered very different to fMRI, it is not an uncomfortable procedure.

Considering the basic cognitive neuroscientific techniques that could be employed by the market researcher who wished to develop a specialized neuromarketing profile, fMRI is an excellent tool for the localization of a *specific area* of the brain implicated in a particular task. However, fMRI is dependant on cortical hemodynamics and, as such, can suffer from a time lag. It is, thus, a poor tool for study of the timing of cortical activity. Understanging the timing of cortical activity can be important in a range of neuromarketing applications, particularly when exploring the evolution of activity over time, such as when for example examining the reactions to advertisements. More importantly, engendered activation that is revealed with fMRI could reflect a range of different cortical processes, processes that may or may not have any direct relevance to the cognitive task at hand (see e.g., Kosslyn, 1999). On the other hand, MEG is less well suited to localise brain activity to a precise degree (although it is possible to do so), particularly within deep-brain structures. However, as MEG detects the very small electromagnetic changes in the brain, it is freed from the temporal constraints that the hemodynamic response imposes. Thus, taking in hand the caveats regarding deep brain structures above, MEG also allows study of the oscillatory frequency of neuronal clusters that are linked to a specific event – be it a response to tasting a particular brand of cola, or perceiving a particular advertisement.

COMPARING fMRI AND MEG FOR THE PURPOSES OF MARKETING RESEARCH

Taking in hand the fact that collecting data with both techniques requires similar efforts from the subjects and similar efforts with regards to the analysis of that data it should be clear that fMRI and MEG each have specific strengths and weaknesses when it comes to resolution (either spatial or temporal), which in turn make them more or less appropriate for different research situations. Yet the demands of the specific marketing research context necessitate certain minimum standards of both resolutions. For example, one must be able to identify the activation of specific cortical regions and their interactions. Thus, at the very least a spatial resolution at the regional level is required, and

a spatial resolution much smaller than this (e.g. at the level of individual cells) would be redundant to all intents and purposes in this context. Furthermore, a minimal temporal resolution of seconds would be sufficient to be able to detect significant cortical differences in response to relevant stimuli – although for many relevant tasks this would not be sufficient. Also, as already noted, due to the nature of the MEG sensors it is least sensitive to deeper sub cortical structures, such as the amygdala. While some studies do report amygdala activation with MEG, a combination of the two techniques in a multimodal approach would probably have most utility. Nevertheless, it is appropriate to note that, given advances in recent technology, it is not completely accurate to state that MEG is unable to access deep-brain structures at all, simply that fMRI as a technology is inherently more suited to doing so. MEG of course can *detect* activity in any brain structure, but the problem lies in localising that activity.

Thus, the critical issue in question is to understand the situations that MEG or fMRI may be more suited to examine, and in order to more clearly illustrate the differences between the differing neuroimaging modalities, a number of applications of neuroimaging in marketing-relevant contexts will be detailed below.

ILLUSTRATIVE CASE STUDIES

There is a significant range of critical marketing issues that can be investigated using neuroimaging methods such as fMRI and MEG. In an academic sense, Lee et al (2007) and Lee and Chamberlain (2008) provide details of theoretical advances that can be made with the use of neuroimaging-based research. However, in a commercial sense, significant benefit also looks likely to accrue from the employment of neuroimaging in marketing research. In fact, looking at existing academic research through a commercial 'lens' shows this quite clearly.

McClure et al's (2004) highly publicised, and already mentioned, study comparing Coca-Cola and Pepsi-Cola is perhaps the most obvious example. In brief, the results of this study showed a greater recruitment of emotion and reward-related areas of the brain when subjects were told they were drinking Coca-Cola versus Pepsi. However, in blind taste-testing no differences between the two brands were observed. The direct relevance of such a finding to marketing practitioners is that it can be implied as very strong evidence of the 'brand strength' of Coca-Cola. While it is jumping the gun somewhat to draw the conclusion that Coca-Cola's marketing is 'more effective', one is on more solid ground in suggesting that differences in Coca-Cola's marketing appear to be associated with differences in how consumers experience their use of the product. Given that the difference between the two products was found only when the *brand* was shown to the participants in conjunction with product usage, this is some evidence for the strength of marketing activities in driving consumer experience over and above concrete product characteristics. Yet, this study is unable to tell us *why*, or *which*, marketing activities are effective. For example, it could be simply the fact that Coca-Cola has been a strong brand for far longer than Pepsi which has led to these observed effects, rather than any specific technique used by Coca-Cola, or it could be something as simple as the shape and colour of the packaging used to deliver the experience. Thus, more commercially-relevant research must be designed in such a way that the results of the research are directly interpretable and able to be related to a specific practical question.

Nevertheless, such work also shows that one particularly useful application of neuroimaging for market research is in *evaluating* marketing campaigns. As was seen in the McClure et al (2004) study, the activation observed in the subjects was potentially at odds with their stated preferences or behaviours. Of course, this is a problem that market research has been attempting to solve for many years, as evidenced by the use of specialised qualitative and projective research methods. Yet a well-designed neuroimaging study may be able to contribute in this area as well. That said, there are considerable ethical issues that will need to be taken into account (see Murphy et al, 2008).

The McClure et al. (2004) study was conducted using fMRI. This was an appropriate methodology for the particular problem, since the interest was in uncovering the areas of brain activation in response to a very simple experimental design with little potential for the temporal dimension to be a problem. However, MEG would also be a useful technique to investigate such issues, particularly with recent advances in the spatial resolution of MEG. For example, the increase in temporal resolution enhances the ability to understand how different areas of the brain activate in sequence (connectivity analysis), as well as in understanding the *type* of activation engendered by specific stimuli (using frequency analysis).

An example of research with commercial implications conducted using MEG was published in an academic context by Ambler et al. (2004). In this study, the researchers were interested in uncovering how consumers made brand choice decisions. By designing an experiment where brand choice making is compared against a baseline choice situation, one can gain an indication of whether the brand choice situation is unique in any manner. Ambler et al. (2004) designed a study where subjects were placed in an MEG scanner, and asked to follow a 'virtual tour' of a typical UK supermarket. Participants were asked to make a series of choices among three brands, and later to fill in a questionnaire about their familiarity with each brand. A control group was shown a repeat of the virtual tour, but instead of making brand choices were simply asked to pick the shortest item (a height discrimination task).

The findings of Ambler et al's (2004) study showed that brand choices took longer than simple height discrimination, and also that there were different cortical areas activated across the two situations. More specifically, for the brand choice situation, there was stronger activation of the primary visual response, and also in areas related to semantic and memory based processing. The latter suggests the operation of some kind of recall or recognition mechanism for the brand choices.

These findings are interesting, and may form the first step in an understanding of whether advertisements influencing either brand recognition or brand recall may be more effective for certain products or choice situations. Such methodologies are also likely to prove to be more effective measures of brand recall/recognition than typical scales or other measurement techniques – although whether the increase in accuracy justifies the far higher outlay required would need further research.

While there are some considerable flaws evident in the research design itself, they are not related to the modality, and the use of MEG in this research is an excellent example of its potential usage in a market research environment. First of all, the research was able to track activation over time, and measure far more accurately the length of time that relevant areas were active. Because of this, it is possible to design experimental paradigms which include a time dimension of some use. As well as this, it can be seen that the spatial accuracy of MEG was perfectly usable for the purposes of showing activity at the required level. It could be argued therefore that MEG looks likely to be a more flexible imaging modality for the purposes of marketing research, being able to measure changes in brain activity accurately in the context of a real-time experimental design, which may be important in advertising evaluation, or many other consumer-relevant contexts (e.g. the 'virtual supermarket tour').

For example, the superior temporal resolution of MEG has lead to many marketing-relevant discoveries that would be impossible with fMRI. In a similar study to Ambler et al. (2004), Braeutigam (2005) showed that initial visual cortex activity occurs within 100 milliseconds from the onset of the stimulus when the subject is presented with a consumer based choice compared to merely judging the height of the object. In further studies the same research team has identified a range of time points at which various stages of the consumer decision making process such as semantic analysis and memory recall occur (Braeutigam et al, 2001; 2004). MEG data has also

contributed to a recent neuromarketing model which suggests that when presented with an advertisement predictive judgments are made within 50 milliseconds (Bar and Neta, 2008) It should be made clear that an fMRI modality would not be appropriate for such research questions.

However, in order to more comprehensively answer the question of whether fMRI or MEG will be a superior imaging modality for marketing research contexts, it is necessary to develop a programme of comparative research. In particular, based on prior theory, it should be possible to devise a set of experiments which test out well-established marketing theories using both modalities. Theory (such as that presented above) would suggest that either one or the other would be more suitable to any given situation, and the key task is to discover whether in reality this is the case. Such work is of critical importance before researchers rush in to apply these imaging methods to their marketing research problems.

CONCLUSIONS

The aim of this working paper was to explore the use of different neuroimaging modalities in neuromarketing research. In doing so, a brief overview of the brain reward system, and the imaging technologies themselves, was given. It was shown that both fMRI and MEG have potential utility for neuromarketing research tasks, and each has specific strengths and weaknesses. fMRI does currently have an advantage at precisely locating brain activity, particularly in deep areas of the brain, yet MEG has far superior ability to track activity over time. MEG is also able to measure the frequency of brain activity, which may be of significant interest itself. However, in a general sense MEG is less precise in locating the activity, and is less able to detect activity in deeper brain structures. That said, when strong expectations of where activity should occur – such as would be the case in almost all neuromarketing studies which are based on existing neuroscientific theories and knowledge – the spatial resolution of MEG is far improved, and it is able to localise activity to a

level comparable with fMRI. Furthermore, with the use of newer methodologies such as synthetic aperture magnetometry (SAM), the spatial resolution of MEG is improving significantly.

Subsequently, examples of the use of fMRI and MEG in marketing-relevant situations were described, showing clearly the situations and questions that each modality is better suited to answer. In conclusion, while it is certainly the case that general arguments for either fMRI or MEG as the superior tool can be advanced, these arguments are somewhat facile given that there is virtually no situation in which both tools would be of equal usefulness and where one was choosing between them on technical grounds. Instead, it is important that neuromarketers understand exactly what each modality is best suited to, in order to design appropriate experimental paradigms. However, it is certainly the case that MEG is likely to be at least as useful as fMRI in neuromarketing research and – certainly where cortical rather than deep structures are examined – there is a case that it is in fact the superior modality.

More specifically, if one is able to generate strong theories about where one *should* see brain activity, and when, then MEG is able to provide a source localization at least equivalent to fMRI when conducted correctly. It is certainly the opinion of these authors that all applied neuromarketing research should be done in this context, rather than simply examining subjects in an exploratory context to 'see what lights up in their brains' (see also Lee, Broderick and Chamberlain 2007; Senior and Lee, 2008). This echoes calls in the related field of social cognitive neuroscience for a theory-driven rather than exploratory approach (e.g. Oschner and Lieberman, 2001). In such cases, MEG is a highly appropriate modality since it demands strong theory prior to analysis. Furthermore, if questions regarding the timing of activity are of interest (such as points within a TV ad or shopping experience where memory encoding or cognitive processing occurs, or arousal increases), then MEG is the far superior methodology. Finally, if recent findings which suggest that the frequency of brain activity indicates different 'types' of activity, then MEG will be much more useful than fMRI –

which is essentially unable to examine this issue. While EEG and SST may also be able to explore these issues, they are completely restricted to examining activity at the surface of the brain even though they may have some practical advantages in terms of size and portability. Thus, it could be concluded that – for most situations of relevance to neuromarketing research – MEG may be the more useful modality when compared to fMRI, despite the popularity of fMRI in recent times. However, of course this conclusion may be debatable, and it is our intention that such issues are debated within the scientific and research communities – hence this working paper.

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