Chapter 4

An Overview to Neuromarketing Research Methods

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Abstract: Neuroscience research methods provide a deeper understanding of the cognitive processes and underlying mechanisms that help explain consumer behaviors. The human brain that controls intelligence, senses, body movements and behavior is the most complex organ and the place where emotions are generated and controlled (Abhang, Gawali, Mehrotra, 2016). It yields two kinds of signals that scientist has exploited “to get a better look at what is going on under the hood” (Genco, Pohlmann, Steidl, 2013). Namely, the first is blood flow in the brain, and the second – the electrical activity in the brain. Although both have produced robust bodies of research, they are not without controversies as emerging fields. What is clear, however, is that understanding what is happening in the neuromarketing techniques is essential for anyone who believes that marketers can change the probability of a favorable response from consumers (as a valid measure of consumers’ attitude towards products, packaging, design, price, promotion, etc.), more accurate than self-reports. Therefore, the aim of this systematic review is to summarize the techniques, contributions and limitations of the main neuromarketing measures.

Keywords: neuromarketing, PET, fMRI, fNIR, EEG, MEG, TMS

Introduction

Currently, consumer neuroscience is a growing approach to research that is garnering increased attention among academic researchers in the fields of marketing (Lin et al.,

2018). In 2002, the Dutch marketing researcher Smidts coined a term “neuromarketing” (NM) that continues to both enthrall and enrage neuroscientists, psychologists, marketers, market researchers and consumer advocates. According to Schwarzkopf (2015), this term mainly acts as a promise, for it conjures up visions of startlingly new ‘insights’ into consumers’ minds and a grand unification of disparate approaches to the research of consumer behavior. Neuromarketing is a new discipline that uses medical techniques to understand how the central nervous system reacts to marketing stimuli. Lin et al. (2018) point out that by using NM techniques, researchers can overcome the biases inherent in self-reported data derived from surveys and qualitative methods and discover real emotions, feelings, expectations and even hidden restraints of the consumer. The purpose of this chapter is to provide an integrative overview of neuromarketing using brain imaging techniques, separated into recording metabolic and electrical activities. To clarify, apart neuromarketing measures, the neuroscience literature distinguish also psychophysiological measures as well (Table 1).

Table 1. Classification of Neuromarketing and Psychophysiological Tools

Neuromarketing Measures	Recording Metabolic Activities in Brain	PET	Positron Emission Tomography
		fMRI	Functional Magnetic Resonance Imaging
		fNIR	Functional Near-Infrared Spectroscopy
	Recording Electrical Activities in Brain	EEG	Electroencephalography
		MEG	Magnetoencephalography
		TMS	Transcranial Magnetic Stimulation
Psychophysiological Measures	Without Recording Brain Activities	ET	Eyetracking
		EDA	Electrodermal Activity (formerly called GSR)
		fEMG	Facial Electromyography
		FACS	Facial Action Coding System
		IAT	Implicit Association Test
		MPR	Measuring Physiological Responses
		SMH	Somatic Marker Hypothesis

Note. own elaboration based on Zurawicki (2010) and Holmqvist et al. (2011).

Recording Metabolic Activities in Brain

Nowadays, two main measurement technologies are used in neuroscience to derive images of brain activity by measuring blood flow in the brain (fMRI and PET). They are based on the anatomical principle that mental activity increases demand for oxygen or glucose in activated regions in the brain (and this need is met by increased blood flow to the region) (Genco, Pohlmann, Steidl, 2013). Brig and Cole (2009) notice that medical imaging continues to evolve at a blistering pace and recent developments in molecular imaging have created a lot of excitement not only in the medical fraternity, but also in neuromarketing field.

Figure 1. PET scanner

Retrieved from <https://eu.medical.canon/product-solutions/computed-tomography/celesteion-pet-ct/>.

Note: The most recent innovation in PET scanners is the dual-modality PET/CT. By combining nuclear medicine and radiological imaging modalities it is possible to add anatomical to functional information (Langer, 2010).

PET

Positron emission tomography (PET) is a three-dimensional diagnostic imaging technique using compounds labelled with positron-emitting radioisotopes to measure cell metabolism (Langer, 2010). PET uses radiolabeled molecules to image molecular interactions of biological processes in vivo, and has been widely adopted as an important clinical modality for neurological oncological and cardiovascular applications. PET imaging is based on detecting two time-coincident high-energy photons from the emission of a positron-emitting radioisotope. According to Vaquero and Kinahan (2015) it offers more translational possibilities than any other modality due to its combination of sensitivity and quantitative accuracy. Similarly, Jones and Townsend (2017) indicate that PET is the most specific and sensitive means for imaging molecular interactions and pathways within the human body.

This molecular imaging technique is based on the detection of radioactivity emitted after a small amount of a radioactive tracer is injected into a peripheral vein¹ (the used dose is similar to this one used in computed tomography) (Lai, Yen, Chang, 2007). The tracer after being absorbed by the body travels through the subject's blood and collects in organs and tissues (the investigation begins after at least one hour). Then a narrow table slides patient into a large tunnel-shaped PET scanner that detects signals from the tracer and a computer changes the signals into 3D pictures that shows how organs and tissues are working (MedlinePlus, 2018). A common analytical approach in PET imaging is to statistically compare a patient's PET images on a voxel-by-voxel basis to a database of healthy individuals matched for age and gender (called normative database) (Slough, Masters, Hurley, Taber, 2016). Voxels in which the patient differs by more than 2.5 standard deviations indicate areas of significantly altered function (Shokouhi, Claassen, Riddle, 2014).

¹ The tracer is administered as an intravenous injection usually labelled with oxygen-15, fluorine-18, carbon-11, or nitrogen-13.

PET is an instrument which is capable of pointing out various phenomena such as brain blood flow, blood volume, glucose and last but not least oxygen consumption. That is because the brain structures which have higher concentration of injected radiopharmaceutical emit higher amount of radiation – meaning they are more active in terms of the cell metabolism or blood circulation (more actively working areas are highlighted) (Zurawicki, 2010).

PET is a very costly method, quite uncomfortable for the subject (mainly due to the stationary position and noise generation), and less and less used in neuromarketing specific research (Sebastian, 2014). Due to the fact that PET involves radioactive material injection, it is not suitable for everyone (especially it is not recommended to conduct PET scan in case of pregnant women and infants, and individuals who have an allergic reaction to the tracer). Moreover, the spatial resolution may be seen as a next limitation, determined by the variability in estimating the interaction point of the 511 keV photon in the scintillator (Vaquero, Kinahan, 2015). The temporal resolution is poor, because it takes time before enough radioactive “ticks” can be counted (the greater activity in the brain region, the more radioactive tracer is present in that region, and the stronger PET signal at that location).

fMRI

Nowadays, due to the constant changes in consumer behavior in the world full of sophisticated technologies, functional magnetic resonance imaging (fMRI) is definitely a promising alternative research method (Ruanguttamanun, 2014). According to Genco, Pohlmann and Steidl (2013) fMRI is at present the most popular neuroimaging technique for academic neuroscience research. It is a class of imaging methods developed in order to demonstrate regional, time-varying changes in brain metabolism that can be consequent to task-induced cognitive state changes or the result of unregulated processes in the resting brain (Glover, 2011). fMRI aims to determine the neurobiological correlation of human behavior by locating the active parts of the brain during the experiment (Kulich, Maciewicz, Scrivani, 2009) and require the subject to perform a particular action in order to trigger a dynamic uptake of oxygen into the brain. This is because fMRI recordings are based on the subsequent increase in oxygen demand from the brain tissue upon the execution of a certain stimulus, whether it is motor, sensory or emotional.

There are two principal techniques of functional MRI: the blood-oxygen-level dependent (BOLD) technique and the dynamic or exogenous technique (Hare et al., 1998). The first technique is the favored method because no intravenous contrast medium is required. Chow et al. (2017) note that the majority of fMRI studies make use of BOLD contrast imaging, which involves mapping particular regions of a functioning brain, from the changes in blood oxygen. Blood flow in the brain is very locally controlled in response to oxygen and carbon dioxide tension of cortical tissue. As with a PET scanner, in the fMRI experiment, the subject is scanned while lying on their back in a narrow, long tube and remains still throughout the testing², in order not to compromise the

² If the person moves his or her head as little as two millimeters, the resulting image is blurred into meaningfulness. And because speaking causes head movement, verbal responses are impossible to collect.

collected data. This tube is surrounded by magnets that generate electric fields when activated. This method offers very accurately identifying increased activity in a certain brain area while a stimulus situation is being presented (Sebastian, 2014).

Figure 2. fMRI scanner

Retrieved from <https://www.siemens-healthineers.com/en-ca/magnetic-resonance-imaging>.

In order to understand how the fMRI works, it is imperative to mention that blood contains iron, which is part of hemoglobin, which transports oxygen throughout the bloodstream. Iron atoms are capable of generating changes in the magnetic field around them (Sebastian, 2014). When a specific region of the cortex increases its activity in response to a task, the extraction fraction of oxygen from the local capillaries leads to an initial drop in oxygenated hemoglobin (oxyHb) and an increase in local carbon dioxide (CO₂) and deoxygenated hemoglobin (deoxyHb). Following a BOLD response lags (of 1 to 2 seconds behind the stimulus – in order for the vascular system to respond), cerebral blood flow increases (it peaks at 5 seconds after the stimulus) delivering a surplus of oxygenated hemoglobin, washing away deoxyhemoglobin and in this large rebound in local tissue oxygenation which is imaged³. So the reason fMRI is able to detect this change is due to a fundamental difference in the paramagnetic properties of oxyHb and deoxyHb (Glover, 2011). Interestingly, the voxel representing the area of activation is usually defined as covering a few million neurons (Heutzel, Song, McCarthy, 2009).

³ The different levels of oxygen usage are frequently illustrated with a pseudocolor scale in the images acquired. In the commonly used four-color scale, red indicates the highest level of oxygen uptake, yellow is an intermediate level of uptake, green indicates the normal level of oxygen, and blue indicates oxygen levels that are lower than normal (Glover, 2011).

Since scanners produce strong magnetic fields, subject will need to remove all metal objects before having a scan (therefore, metal objects and certain medical devices – such as hearing aids, surgical implants, clips, and pacemakers, are not allowed in the vicinity of the MRI scanner for safety reasons). In the case of neuromarketing research individuals with claustrophobia should not be signed up to take part in an fMRI study. Moreover, participants need to be free from current psychological and neurological diagnoses and have normal hearing, and normal, or corrected-to-normal, vision.

Whereas only limited conditions can be tested in the fMRI-scanner (and only specific types of stimuli can be shown while the participant is lying in the scanner), many researchers question whether economic decision making can truly be measured (and generalized) in such a restricted situation (a.o. Shimokawa et al., 2009; Ariely, Berns, 2010; Ayaz et al., 2013). fMRI usage has been relatively limited due to the high cost of machinery (in terms of installation, training and maintenance) and the high level of required technical expertise. Furthermore, some subjects may find the experience claustrophobic, or at least highly agitating due to the noise and still position required, not mentioning the novelty of medical research. As mentioned by Genco, Pohlmann and Steidl (2013), in case of consumer and marketing research, focused on identifying subtle variations in emotional response, this method can produce a confounding effect difficult to disentangle from participants' responses to the stimuli themselves.

fNIR

The third metabolic recording method opens a promising new avenue for studying and understanding shopper's behavior, since mobile fNIR enables marketing management to collect neural data from shoppers and analyze neural activity associated with real-life settings (Krampe, Strelow, Haas, Kenning, 2018). Similarly, Kopton and Kenning (2014) persuade that fNIR is a new and promising tool for investigating economic decision making both in field experiments and outside the laboratory.

Functional near-infrared spectroscopy (fNIR) is an optical brain imaging technique that enables monitoring of changes in cerebral blood oxygenation related to human brain functions (Ayaz et al., 2011). Subjects wear an fNIR sensor (infrared light sources and detectors mounted in a flexible band)⁴ on the forehead – that detects oxygen levels in the prefrontal cortex and provides real-time values for oxy-hemoglobin (HbO) and deoxygenated hemoglobin (HbR) – due to the hemodynamic response – the rapid delivery of oxygenated blood to active cortical areas through neurovascular coupling⁵ (Ayaz et al., 2013).

Although, recordings from fNIRS are similar to fMRI, the measurement area is limited to the outer cortex and has lower spatial resolution (mm versus cm) (Batula, Mark,

⁴ Near-infrared light, with a wavelength spectrum of circa 650–950 nm, passes through biological tissue without difficulty, and can non-invasively illuminate several centimeters of the tissue (Jackson, Kennedy, 2013; Scholkmann et al., 2013).

⁵ When a group of neurons are more active, local blood flow changes in response (and in turn, changes the local oxy-/deoxy- hemoglobin concentrations) — this is known as neurovascular coupling.

Kim, Ayaz, 2017). However, fNIRS can measure at a higher temporal resolution to capture additional frequency bands and does not require subjects to lay down in a supine position in restrictive and artificial lab environments with the loud noises generated by fMRI. As noted by Batula et al. (2017), despite the lower temporal resolution and time delay of the hemodynamic response compared to EEG measurements, fNIRS provides a unique trade-off between temporal and spatial resolution and moreover, it is free from most artifacts, such as muscle activity and eye blinks. In the common configuration, light sources and detectors are placed on the scalp and two wavelengths of light are transmitted through the top layer of the cerebral cortex. Picture 3 shows fNIR sensor pad that contains 4 light sources (middle row) and 10 light detectors (black spots) forming 16 optodes (measurement locations – four for each light source).

Figure 3. fNIR devices (data acquisition control box and fNIR sensor pad)

Retrieved from <https://biopac.com/product-category/research/fnir-optical-brain-imaging>.

According to Ayaz et al. (2011), light at wavelengths between approximately 700 and 900 nm can pass through skin, bone, and water, but it is absorbed primarily by oxy- and deoxy-hemoglobin (HbO and HbR respectively). Due to the fact that HbO and HbR have different light absorption properties, the relative changes in HbO and HbR, and therefore the change in oxygenation of the tissue, can be calculated from changes in the reflected dual-wavelength light using the modified Beer-Lambert law⁶ (Cope, 1991). However, fNIR does have some limitations. Particularly, it enables to examine only cortical activity, with the limited depth penetration of near-infrared light into the skull. Moreover, hair can interfere with the transmission of light among the source, the scalp, and the detector, so researcher must be prepared to avoid this possibility (Sera-glia et al., 2011).

⁶ Also known as Beer's law, relates the attenuation of light to the properties of the material through which the light is travelling.

Recording Electrical Activities in Brain

The second basic class of mapping technique is localizing the underlying electrical activity of the brain. Such techniques enable the recording of brain activity directly through scalp-surface detection of electrical and magnetic signals emitted by the brain (Genco, Pohlmann, Steidl, 2013). Electrical measurement techniques compared to blood flow provide much poorer spatial resolution, because they measure only signals at the scalp surface where the sensors are located.

EEG

The electroencephalogram (EEG) is an efficient and relatively inexpensive method for the study of changes in brain-behavior relations (Bell, Cuevas, 2012). The change in the human brain signal and its main spectral bands of Delta (0–4 Hz), Theta (3–7 Hz), Alpha (8–12 Hz), Beta (13–30 Hz), and Gamma (30–40 Hz) is observed to examine consumers' cognitive or affective processes in response to presented marketing stimuli (Mostafa, 2012). The applications of this method are extremely wide-reaching, as they allow investigators to explore a nearly infinite number of domains where it is of interest to understand the relative timing of neural events (Light et al., 2010). The recording of EEG signals is done by placing several electrodes on the participant's scalp (usually in form of a cap) and to improve the conduction of impulses to electrode, a gel is recommended to be applied.

The electric current produced by a normal human brain has order of a few microvolts. These voltage fluctuations are the result of ionic current that flows between brain and the neurons. Neurons communicate with each other via electrical impulses. The electric potential picked up by a single neuron is very small and thus it is impossible to detect. Each electrode reflects the summation of the synchronous activity of thousands or millions of neurons that have similar spatial orientation, so the EEG determines the summation of the synchronous activity of a large number of neurons present in the brain (Kaur, Kaur, 2015).

The amplitude of EEG signal may vary from 10 to 100 micro volts with a frequency range of 1–100 Hz. The signal extracted from electrodes – called raw EEG signal – may include some non-cerebral signals called artefacts. The EEG signals may be contaminated mainly by movement related potentials, eye blinks, movement of facial muscles as well as by the environmental artefacts like line noise, pulse and electrode stabilization (Kaur, Kaur, 2015). So in order to possess readable EEG signal, the raw signal must undergo various processes, including filtration. When planning a recording session, an investigator must balance the need to obtain a sufficient quantity of data to provide reliable estimates of EEG signal while minimizing participant burden, because with longer sessions, emotional state can change within session (Smith, Reznik, Stewart, Allen, 2017). Having in mind this constraint, when projecting EEG research – among two main methods presented in the literature – such as evoked potentials (EP)⁷ recording

⁷ Meanwhile Abhang, Gawalin, Mehrotra (2016) did not distinguish evoked potential (EP) from the event related potential (ERP), one remark specifying the difference between EPs and ERPs is necessary. An

and calculating asymmetry – the later seems to be more attractive for participant. In the first case, there is a need to apply repeated stimuli (many trials are required because the waveform is extracted by averaging across all trials of the same stimulus) – because evoked potential is an electrical potential recorded from the nervous system of a human following presentation of a stimulus, as distinct from spontaneous potentials as detected by EEG.

Figure 4. Wireless EEG headset

Retrieved from <https://imotions.com/hardware/abm-b-alert-x24/>.

Note: B-Alert X24 has 20 channels of high-quality EEG, plus 4 optional channel for ECG, EMG, or EOG.

One commonly cited metric which neuromarketing companies focus on is the degree of “emotional engagement”, that is measured by the frontal asymmetry⁸ in the EEG output (index can be computed in a fairly simple manner from raw frontal EEG data). This measure involves computing the difference in activity between left frontal and right frontal regions, generally in the alpha band (but many recent research include also beta and gamma band – for further information see Garczarek, Disterheft, 2018). Neuropsychologists have consistently found that higher engagement of the left – relative to the right frontal brain – is related to positive feelings and higher engagement

event-related potential (ERP) is any stereotyped electrophysiological response to an internal or external stimulus. In simple terms it is any measured brain response that is the direct result of a thought process or perception. ERPs were originally called evoked potentials (EPs) because they were electrical potentials that were evoked by stimuli (as opposed to the spontaneous EEG rhythms. In many cases EP = ERP, but it is important to emphasize that EPs are time locked and averaging typically brings them out, whereas ERPs are not time locked and averaging may hide the potential (KCE 2009).

⁸ The frontal lobe is the emotional control center of the brain, responsible for problem solving, judgment and motor function. It controls thinking, planning, organizing, short-term memory and movement (Abhang, Gawalin, Mehrotra 2016).

(Coan, Allen, 2003), that may serve as an index of approach motivation or related emotion (that is activated when an individual is moving towards goals or experiences positive emotions). Conversely, relatively increased right-frontal activity may serve as an index of withdrawal motivation or related emotion (a lateralized withdrawal system is involved in negative affect or the motivation to move away from potentially dangerous situations or stimuli) (Davidson, 1998).

Frontal EEG asymmetry is now employed by scientists worldwide to study constructs such as temperament and personality, various types of psychopathology, motivation, emotion, and cognitive control. Although, according to Pizzagalli (2007) EEG is one of the more favorable brain imaging methods, (especially for use with infants and children), there is one major caveat of this methodology. The EEG signal has excellent temporal resolution, but it has poor spatial resolution. Apart from this issue, when conducting EEG research, scientists must prepare proper questions (as well as relevant stimuli), and the patient must be given instructions when the EEG is scheduled (including: not to consume alcohol, caffeine and cigarettes before the test, to avoid using hair styling products, sleep at least 8 hours, etc.).

It is worth to mention also about technology patented and used by Neuro-Insight (2019), known as Steady-State Topography (SST), that records and measures electrical signals at the scalp in order to build a second by second picture of activity in the brain. It is essentially a refinement of EEG, that offers serious advantages for marketing (a derivation of EEG/ERPs using an evoked potential to an ongoing oscillating stimuli). This method for observing and measuring human brain activity uses presence of a dim sinusoidal visual flicker presented in the visual periphery. The sinusoidal flicker elicits an oscillatory brain electrical response called Steady State Visually Evoked Potential (SSVEP), and neural speed can be calculated by measuring the delay between the visual flicker and the SSVEP response (Seixas et al., 2015). So task related changes in brain activity are determined from the SSVEP measurement and decreases in the magnitude of this potential are correlated with an increase in cognitive processing demand (Gordon, Ciorciari, 2017). Making the important distinction between EEG and SST, one must remember that EEG measures neural amplitude, which ambiguously describes a subject's brain activity, while SST measures the speed of electrical activity and has a higher signal to noise ratio. This means it provides clear insight into precise brain activity after only one test showing of an ad, while the other methods require 6 to 10 trials. SST overcame the short-comings of raw EEG which has "the potential for errors – that is, interpreting spurious signals as real" (Neuro-insight, 2019).

And last but not least, the term quantitative EEG (qEEG) requires further explanation. The qEEG is an extension of the analysis of the visual EEG interpretation which may assist and even augment our understanding of the EEG and brain function. This multi-channel EEG data is processed with various algorithms, such as the "Fourier" classically, or in more modern applications "Wavelet" analysis and the digital data is statistically analyzed. The processed EEG is commonly converted into color maps of brain functioning called "Brain maps". qEEG gives the ability to view the dynamic changes taking place throughout the brain during cognitive processing tasks, and this novel approach can be used to assist us in determining which areas of the brain are engaged

and processing efficiently. The QEEG method is finding increasingly more users because it supports the biomarker hypothesis and allows for more precise information about the respective clinical picture (Qeegsupport, 2018).

MEG

Magnetoencephalography (MEG) is the measurement of the magnetic field generated by the electrical activity of neurons (Singh, 2014). MEG directly records the magnetic fields associated with synchronous activity of neuronal populations, and picks up transient and sustained evoked activity. It also records the magnetic fields rhythms with millisecond-range temporal resolution (Hari, Puce, 2017). As noticed by Singh (2014), the magnetic permeability of biological tissues is almost the same as that of empty space and so the magnetic field is not distorted by scalp or skull. Moreover, MEG is a noninvasive imaging technique that does not involve exposure to ionizing radiation, does not make any operational noise, and does not requires the complete absence of subject movement during recording. However, this expensive method requires a magnetically shielded room and superconducting quantum interference detectors to measure the weak magnetic signals in the brain.

Figure 5. Latest generation MEG system

Retrieved from <https://elekta.com/diagnostic-solutions>.

It is performed using a dewar that contains multiple sensor coils (the helmet looks like a large hair dryer), which do not touch the patient's head. At the cellular level, individual neurons in the brain have electrochemical properties that result in the flow of electrically charged ions through a cell, and the electromagnetic fields are generated by the net effect of this slow ionic current flow. While the magnitude of fields associated with an individual neuron is negligible, the effect of multiple neurons excited together (50,000–100,000) in a specific area generates a measureable magnetic field outside the head. Due to the fact that these neuromagnetic signals generated by the brain are extremely small (a billionth of the strength of the earth's magnetic field), MEG scanners require superconducting sensors – SQUID, superconducting quantum interference device (that are bathed in a large liquid helium cooling unit at approximately –269 degrees C, and due to low impedance at this temperature, they can detect and amplify magnetic fields generated by neurons a few centimeters away from the sensors). A magnetically shielded room houses the equipment, and mitigates interference (llab.washington, 2018). This sophisticated instrument and computer software work together to detect and record the activity of neurons as the patient lies still or completes a series of tasks, such as listening to a series of words or looking at pictures (Radiologyinfo, 2018). Patients with a vagus nerve stimulator (VNS), pacemaker or similar device may not be able to undergo an MEG study. Furthermore, jewelry and other accessories should be removed prior to the MEG exam and participant should not wear makeup (which could include metallic substances) or hair products on the day of the procedure.

MEG is usually combined with a magnetic resonance imaging (MRI) to get a good structural perspective. This combination of MEG and MRI is called magnetic source imaging (MSI). Future MEG breakthroughs in understanding brain dynamics are expected through advanced signal analysis and combined use of MEG with hemodynamic-imaging (fMRI).

TMS

Transcranial Magnetic Stimulation (TMS) is a noninvasive method for local stimulation of cerebral cortex. TMS can be used not only to demonstrate causal brain-behavior relations, but by varying the duration and onset of the virtual lesion – TMS can also reveal the time course of normal processing. When applied to the scalp, the magnetic field induces electrical activity in the underlying brain tissue, temporarily disrupting local cortical information processing. This transient interference effectively creates a short-lasting “virtual lesion” (Sliwinska, Vitello, Devlin, 2014). Stimulation that interferes with task performance indicates that the affected brain region is necessary to perform the task normally.

This method relies upon the properties of electromagnetic induction – a rapidly changing magnetic field is generated when a high-voltage current is passed through a coil. As explained by Bolognini and Ro (2010), when this coil is held in close proximity to any electrically conducting medium, such as the brain, this time-varying magnetic field induces current in a direction opposite to the original current in the coil. So, through time-varying current in a stimulation coil, TMS generates strong alternating

magnetic field pulses that can permeate the electrically poorly conducting skull and evoke action potential of neurons in the focus of the stimulation coil. Attenuated in the tissues of the head, a TMS pulse can effectively reach at least 3–4 cm below the scalp and this depth allows TMS to be used to probe, or treat, virtually the entire area of the human cortex (Goetz, Deng, 2017).

Figure 6. TMS + The NBT System

Retrieved from <https://nexstim.com/healthcare-professionals/technology/>.

Note: The Navigated Brain Therapy (NBT®) System is a device that uses navigated transcranial magnetic stimulation (nTMS) for use in stroke rehabilitation. Navigation is achieved by visualizing the electric field (e-field) generated by the TMS coil in a 3D image rendered from the patient's MRI scan.

This technique offers a non-invasive method for drawing causal brain-behavior inferences and investigating the temporal dynamics of online neural information processing in both healthy adults and neurological patients. Depending on stimulation parameters, TMS can excite or inhibit the brain, allowing functional mapping of cortical regions and creation of transient functional lesions (Hallett, 2000). As indicated by Volz et al. (2014), unlike subthreshold neuromodulation techniques, TMS pulses can trigger a neuron's endogenous signal transmission mechanism, which amplifies the stimulus and transmits the signal to other neurons. Advantages of the technique over lesion-deficit studies include better spatial-temporal precision of the disruption effect, the ability to use participants as their own control subjects, and the accessibility of participants (since only individuals that have a pacemaker fitted or have any metal in or on their bodies and pregnant woman are unable to take part). Limitations listed

Table 2. Neuromarketing Research Aims and Results Examples

Method	Au- thors	Field	Research goal	Results
PET	Smith et al. (2002)	Choices between gambles	Attitudes about payoffs and beliefs about the likelihood of outcomes interaction effects	The interaction between belief structure (ambiguity/risk) and payoff structure (gain/loss) shapes the distribution of brain activity during choice. A simple manipulation of belief structure and payoff structure produces focal activations and deactivations that suggest two disparate, but functionally integrated, choice systems with sensitivity to loss: a neocortical dorsomedial system related to loss processing when evaluating risky gambles, and a more primitive ventromedial system related to processing of other stimuli.
fMRI	Schaefer et al. (2006)	Choice between different car brands	Neural correlates of culturally based brands	Activation of a single region in the medial prefrontal cortex is related to the logos of the culturally familiar brands. The results were interpreted as self-relevant processing induced by the imagined use of cars with familiar brands, which suggest that the prefrontal cortex plays a crucial role for processing culturally based brands.
fNIR	Meyerding, Mehlhose, (2018)	Brand- and label-related prefrontal cortex activation	Explain the impact of brands and food labels on prefrontal cortex (PFC) activity	Significant increases in PFC activity at the individual level were measured. The organic food label led to a higher activation than the regional label among 94% of the subjects; both labels led to an increase in activity compared to the same products without any labeling. The strong cola brands, Coca-Cola and Pepsi, led to an increase in activation while drinking and viewing the respective brand cues compared to the weak brands, Topstar and Vita Cola.
EEG	Ohme et al. (2010)	Potential of TV advertisements to generate approach related behavior	Identify frontal cortex activation in reaction to TV ads	Dominant reactions were present only in response to one of the tested ads. Target group respondents reacted in such way to emotional part of the ad, as well as to its informational part (including product-benefit, product, and brand exposure scenes). No similar pattern was found for the remaining two ads. It yields a conclusion that frontal asymmetry measure may be a diagnostic tool in examining the potential of advertisements to generate approach related tendencies.

Method	Authors	Field	Research goal	Results
MEG	D'Hondt et al. (2013)	Emotional coding of visual space	Behavioral and cerebral impact of peripherally presented affective stimuli on the subsequent processing of foveal information	Participants responded more quickly when the location of the peripherally presented emotional scene was congruent with the direction of the central arrow that followed it. This behavioral bias was correlated with a similar congruence effect in a left frontocentral MEG component at 135 msec, which suggest that the prior spatial distribution of emotional salience, like physical salience, grabs attentional resources and modifies the performance in the center of the visual field.
TMS	Pitcher et al. (2012)	Face and body visual perception	Determine when category-selective visual cortex first contributes to face perception	Category-selective cortical regions are critical for two functionally distinct stages of visual object recognition: an early, presumably preparatory stage that is not category selective occurring almost immediately after stimulus onset, followed by a later stage of category-specific perceptual processing.

Note. own elaboration.

by Sliwinska, Vitello and Devlin (2014) include concurrent auditory and somatosensory stimulation that may influence task performance, limited access to structures more than a few centimeters from the surface of the scalp, and the relatively large space of free parameters that need to be optimized in order for the experiment to work.

Conclusions

The increasing popularity of using neuroscientific methods as a tool in new domains is due to the limited possibilities available in classical market research. Although understanding how customers think, feel, and respond to a company's offerings has always been rather difficult (Hsu, 2017), consumer neuroscience helps obtain a more complete and objective understanding of consumer desires, which may consequently assist companies to adjust their marketing strategies (Hubert, 2010). The field of neuromarketing should be considered a legitimate and important area for future research, despite the public's lack of knowledge on its practice by companies, physicians, and scientists. What is more, lack of validation of neuromarketing techniques in controlled academic studies has been a sore spot for years (Fisher, Chin, Klitzman, 2010) with neuromarketing companies bearing no special duty towards transparency. Since neuromarketing has **socially and ethically relevant implications** it is important to raise considerations for the responsible conduct of research and the public understanding of neuroscience. This is all the more important when descriptions of neuroscience research are accompanied by images of the brain — even though these images may have no actual impact on the objective validity of those findings (the colorful results appear as such only after

extensive image processing and statistical analyses, and in the context of a specific experimental paradigm).

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