# How neuroscience contributes to neuromarketing

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## ABSTRACT
The purpose of this study is to show how and where neuroscience contributes to neuromarketing. In order to show the contribution to neuromarketing, a literature research on neuroscience, consumer neuroscience and neuromarketing has been done. Main findings of this paper suggest that the combination of neuroscientific tools and non-neuroimaging tools add validity to research findings and it will establish brain behavior relationships in order to understand underlying consumer preferences and choices. Thus far, the proposed framework for assessing the contribution of neuroscience to consumer research cannot be used for neuromarketing due to the lack of general converging evidence. However, some neuromarketing findings do support some of it, though it is not sufficient enough to contribute to neuromarketing yet. The implication for neuroscience, and thus for neuromarketing, is the presence of reverse inference. If the activation of a specific area of the brain is relatively selectively, only then it is possible to infer with sufficient confidence that the particular mental process is engaged when there is activation in that area of the brain.

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## Keywords
Neuroscience, neuromarketing, consumer neuroscience, contributions, neuroimaging, reverse inference & framework


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# 1. INTRODUCTION

Neuromarketing is still in its infancy and therefore further investigation on the applicability is necessary. Neuromarketing distinguishes itself from consumer neuroscience. Consumer neuroscience includes the scientific proceeding of this research approach (Hubert & Kenning, 2008). Its goal is to enhance the understanding of consumer behavior (Kenning & Plassmann, 2008). Neuromarketing comprises the application of these findings from consumer research within the managerial scope (Hubert & Kenning, 2008). This paper tries to show the applicability of neuroscientific findings and therefore the definitions of neuromarketing and consumer neuroscience will be used disorderly depending on the topic. Several neuroscientific findings have been published, yet there is a lack of clarity and a clear overview is missing in order to show the potential added value of neuromarketing and how neuroscience contributes to consumer research and neuromarketing. This paper includes an exploratory study with the focus on neuromarketing & consumer neuroscience and its findings, what tools are being used, which findings are applicable for use, in what phase neuromarketing currently is and the contributions of neuroscience. Therefore the purpose of this study is to yield insights in the fields of neuroscience & consumer neuroscience and how these insights might be able to contribute to neuromarketing. Neuroscientific findings will be collected and for assessing the contribution of neuroscience to consumer research. Aforementioned neuromarketing comprises the application of the findings from consumer neuroscience. Thus when these findings of consumer neuroscience are applicable, it can be classified as neuromarketing. A framework is used to categorize these findings. When these categorized findings have been classified as applicable, or partly classified as applicable, then it will be able to show how consumer neuroscience contributes to neuromarketing in its current state and therefore it will be able to serve the purpose of this literature research.

# 2. BACKGROUND

A growing interest from science in the use of neuroscientific technologies and methodologies have been visible in the past recent years. Early reports name professor Ale Smidts as the first one to name the use of neuroscientific technologies and methodologies such as functional magnetic resonance imaging (fMRI), electroencephalography (EEG) and magnetoencephalography (MEG), by the field of marketing in 2002 (Solnais, Andreu-Perez, Sánchez-Fernández, & Andréu-Abela, 2013). Where Ale Smidts has been the one who mentioned the use of neuroscientific technologies and methodologies, BrightHouse, an advertising company in Atlanta, has been th (Kenning & Plassmann, 2008)e company which are reported to be the first one to mention the term neuromarketing in June 2002 (Fisher, Chin, & Klitzman, 2010). In their report they mentioned a new business division using the neuroscientific technology fMRI. However, a few years before the first mention of neuromarketing, a patent was filed by two professors from Harvard University for neuromarketing as a marketing tool, though a couple years of silence later, one of them joined a company related to consumer neuroscience (Fisher, Chin, & Klitzman, 2010). In the years before the turn of the century the prefix neuro became a very popular hype in science. The collection of the various domains in the science using the prefix neuro is called the neuroculture. Among this so-called culture is neuromarketing, as well as neuroeconomics, neurotheology, neuroeducation and so on. Each neuro discipline is premised on the search for underlying neural correlates (Frazzetto & Anker, 2009). Neuromarketing is a sub-area of neuroeconomics, while neuroeconomics is a sub-area of neuroscience. Neuroeconomics is a transdisciplinary field which uses neuroscientific technologies and methodologies to identify the neural substrates associated with economic decision making (Zak, 2004), while neuroscience is the study of the nervous system that seeks to understand the biological basis of behavior (Plassmann, Ramsøy, & Milosavljevic, 2012). The combination of biological and psychological sciences led to the interdisciplinary field: neuroscience (Kandel & Squire, 2000). Not everyone is profound of this neuro phenomenon and rather call it neuromania instead of neuroculture. Neuromania refers to the rush from all fields of study to embrace neuroimaging techniques and explain all human phenomena in terms of brain activity. However, it is undeniable that neuroimaging has the power to contribute existing scientific techniques, tools and frameworks (Javor, Koller, Lee, Chamberlain, & Ransmayr, 2013). The term neuromarketing is definition that has been strongly debated in the past few years. Some classify it as a pure scientific field and others rather call it consumer neuroscience (Fisher, Chin, & Klitzman, 2010), while others see it as a business activity (Hammou, 2013). One of the most common cited definitions is that consumer neuroscience includes the scientific proceeding and neuromarketing comprises the application of these findings from consumer neuroscience within the managerial scope (Hubert & Kenning, 2008). Another, rather simple definition of neuromarketing has been published online in The Sun Link in 2004: neuromarketing is the emerging field of studying the brain to help marketers tap into potential customers, or people's unarticulated needs, drives and desires (Dahlberg, 2004). Consumer neuroscience tries to extend methodological approaches in consumer research by introducing physiological measures and by theorizing based on insights from neuroscience (Kenning & Plassmann, 2008). Consumer neuroscience will help to better understand consumer behavior. Management, or marketers will be able to make better informed decisions and they will be enabled to develop strategies that maximizes consumers' welfare, consumers' well-being and it will contribute to profitability of the institution (Kenning & Plassmann, 2008). Before, conventional consumer research saw consumers as a ''black box'', today, with the use of neuroimaging, a look into the so-called black box is possible. This was in a time where only theoretical constructs were used to interpret these bodily processes of consumers and their resulting behavior (Kenning & Linzmajer, 2010). Neuromarketers hope that neuromarketing will enable marketing to determine the truth, or something close, about what consumers really want (Tsai, 2010). Critics of this new emerging field heavily raised their flags, claiming that marketers someday may be able to find the buy button in the brain of consumers and hereby believe that ability to make decisions will be compromised (Wilson, Gaines, & Hill, 2008).

The problem is that a clear overview of the contributions of neuroscience is missing, combined with in what phase neuromarketing currently is and in what marketing practice it can be used. This paper tries to show where neuroscience contributes to neuromarketing. The first question raised is: What is neuromarketing and consumer neuroscience according to the literature. And what neuroimaging & non-neuroimaging tools are being used? Section 3 will address this question. The second question: Which neuroscientific findings have been published that are applicable for use and can the proposed framework from consumer neuroscience be used for neuromarketing? The answers to these questions can be found in section four. Next to the answers for these questions, an overview will be shown to

point the contributions from neuroscience to consumer neuroscience and neuromarketing. This paper is an explorative study and will be entirely based on literature. No experiments or what so ever will be done. Literature will be reviewed and scrutinized. The main source of information for this paper is peer reviewed literature about neuroscience, neuromarketing, and consumer neuroscience. The online database of the University of Twente was used to search for peer reviewed articles, journals and other papers. Articles will be selected and thereafter they will be assessed on quality, accessibility and applicability. The main articles that have been reviewed are those from Solnais et al. (2013), Plassmann et al. (2012), Kenning & Linzmajer (2010), respectively published in the Journal of Economic Psychology, Consumer Psychology and Consumer Protections and Food Safety. Literature research differs from other research in such a way that literature research combines literature of different fields of study and thereby the purpose of this literature research is to combine different findings of different fields of study.

# 3. NEUROMARKETING & TOOLS

In this section the investigation of the scope of neuromarketing will be continued and the different neuroscientific tools available for applying neuroimaging to consumer neuroscience will be discussed. Next to the neuroscientific tools, non-neuroimaging tools will be discussed as well. The question that will be answered in this section is: What is neuromarketing and consumer neuroscience according to the literature. And what neuroimaging & non-neuroimaging tools are being used?

As mentioned before, the most common used neuroscientific techniques are functional magnetic resonance imaging (fMRI), electroencephalography (EEG) and magnetoencephalopgraphy (MEG), however more neuroimaging tools are available for pursuing neuromarketing goals such as positron emission tomography (PET) and transcranial magnetic stimulation (TMS). Definitions of neuromarketing and consumer neuroscience have widely been debated. One of the most common cited definitions is that consumer neuroscience includes the scientific proceeding and neuromarketing comprises the application of these findings from consumer neuroscience within the managerial scope (Hubert & Kenning, 2008). Another definition, or explanation, is that marketing provides theoretical and managerial research problems, while neuroscience sheds light on the brain and its functions, and neuroscientific methods and techniques support the localization and differentiation of the inner processes and conditions (Reimann, Schilke, Weber, Neuhaus, & Zaichkowsky, 2011). So it can be defined as the study of the neural processes and conditions that underlie consumption, their psychological meaning, and their behavioral consequences (Reimann, Schilke, Weber, Neuhaus, & Zaichkowsky, 2011). Another definition of the distinction between consumer neuroscience and neuromarketing is that consumer neuroscience refers to academic research at the intersection of consumer psychology and neuroscience, while neuromarketing refers to practitioner and commercial interest in neurophysiological tools, such as fMRI, EEG, eye tracking and galvanic skin response, to conduct company specific market research (Plassmann, Ramsøy, & Milosavljevic, 2012).

Next to the often used and referred to brain scans, other techniques and tools could and should be used to make neuromarketing more applicable. Paul Postma describes in his book *Anatomie van de Verleiding* three methods which can be used for pursuing neuromarketing goals. According to Postma these methods complement one another. The three methods are: internal reflexes, external reflexes and input/output models (Postma, 2014). Internal reflexes refer to the neuroimaging techniques such as fMRI, MEG, EEG, PET and TMS, while external reflexes refer to body language, eye tracking and facial coding. In this paper it correlates with respectively neuroimaging tools and non-neuroimaging tools. The last method, the input/output method is a rather practical method where simple observations are made and therefore this method is not of particular interest for this study and will not be mentioned any further.

## 3.1 Neuroimaging tools

In this section the neuroimaging techniques which are used for applying to neuromarketing or consumer neuroscience will be explained. Neuroimaging techniques, such as fMRI and EEG, are very popular among neuromarketing literature. An overview of the neuroimaging tools can be found in

### *3.1.1 Functional Magnetic Resonance (fMRI)*

The most prolific and widely used imaging technique for neuromarketing is fMRI. It is derived from MRI and it is used to examine the brain function. During a neuroscientific experiment, a volunteer is placed in a MRI-scanner where marketing stimuli, such as advertisements, are projected to the volunteer. Various information can be *picked* up, such as changes in the volume of blood or quantitative changes in the level of blood oxygenation, but the most import information a neuroscientist can pick up from such an experiment is the BOLD contrast (Lee, Senior, Butler, & Fuchs, 2009). BOLD stand for Blood Oxygenation Level Dependent. BOLD has its origin in the magnetic properties of hemoglobin. Deoxyhemoglobin, hemoglobin without an oxygen molecule attached to it, is paramagnetic. This means that when a blood vessel containing a deoxyhemoglobin is placed in a magnetic field, it will alter the magnetic field in its vicinity. (Tank, Ogawa, & Ugurbil, 1992). Thus, hemogblobin absorbs oxygen and when the level of oxygen decreases, it will changes the paramagnetic characteristics and this signal can thus be shown by fMRI. fMRI has an excellent spatial resolution, this means that it can be used to detect activity in specific and small parts of the brain. However, fMRI has its limits. fMRI has relatively poor temporal resolution, so it cannot predict precisely the timing of a specific activity in the brain (Lee, Senior, Butler, & Fuchs, 2009).

### *3.1.2 Magnetoencephalography (MEG*

Magnetoencophalography (MEG) is neuroimaging technique that is able to measure electromagnetic neural activity with a relatively good spatial resolution and an excellent temporal resolution (Schwartz, Edgar, Gaetz, & Roberts, 2009). The difference between fMRI and MEG is that MEG has a relatively poor spatial resolution compared to fMRI. So it does a poor job at distinguishing the location in the brain where the particular activity originated. However, it can detect activity in the brain at a millisecond level (Lee, Senior, Butler, & Fuchs, 2009). The

spatial and temporal resolution of MEG can be compared to EEG. Therefore, these neuroscientific techniques are suitable to resolve the temporal sequence of the different cortical processing stages involved in brain processes like decision making (Kenning & Plassmann, 2005) Of course, when there is no difference between MEG and EEG, there would be no distinction. Kenning & Linzmajer refer in their paper to multiple studies carried out by Braeutigam et al. where they mention that MEG performs better on visualization of activity in deeper brain structures.

### *3.1.3 Electroencephalography*

Electroencephalography (EEG) measures brain activity by placing electrodes on the scalp of the subject. The signals that are being picked up are a result of voltage differences due to neural activity in the brain. Even though such voltage differences can occur spontaneously, the so-called continuous EEG, certain particular patterns can be picked up when the subject is subjected to various marketing stimuli such as advertisements (Arndt, et al., 2014). As mentioned above temporal and spatial resolution can be compared with the resolutions of MEG, while MEG performs better when activity in the deeper structures of the brain need to be visualized. When a subject is subjected to a marketing stimulus, visual activity in the EEG occurs approximately after 300 milliseconds, depending on stimulus occurrence and intensity (Arndt, et al., 2014). The main advantage is thus the high temporal resolution and should be used to follow the time course of neural activity and should not be used to detect the locations of the neural activity (Kenning & Plassmann, 2005).

### *3.1.4 Positron Emission Tomography*

Positron emission tomography is a quantitative imaging technique and this technique has a high sensitivity, meaning it can detect very small amounts of a tracer. It is not always the case that the distribution of a trace is of interest, but quantification of underlying psychological processes in the brain is. Dynamic PET will then be used (Disselhorst, 2011). Thus when a neuroscientific experiment need to be carried out, a dynamic PET is required. PET is a nuclear medicine imaging technique. After radioactive isotopes have been injected, some of these parts will decay and when they do high-energy gamma-quants will be formed. These gamma-quants are then spatial distributed and can be picked up by PET and be visualized in three-dimensional image. Localization by a PET scan is relatively high (3-6 mm) , thus the spatial resolution is relatively high. However, the temporal resolution cannot for example be compared with the temporal resolution of EEG (milliseconds), while for a PET scan it will take several minutes (Kenning & Plassmann, 2005)

### *3.1.5 Transcranial Mangetic Stimulation*

To gain a better understanding of the interplay between processes in the brain, transcranial magnetic stimulation (TMS) can be used. The spatial and temporal resolution of TMS is very precise (Stanford, et al., 2013). This particular method stimulates the brain by sending electromagnetic impulses to the brain, hereby different locations can be stimulated. By sending such impulses to the brain a magnetic field will be created and in the brain neurons will be activated. This activation can be picked up and measured by TMS. However, the spatial and temporal resolutions are relatively good, but it is limited due to the fact that TMS can only measure the activity of the cortical areas close to the skull (Kenning & Linzmajer, 2010).

Below a schematic overview of the different neuroimaging tools and their spatial & temporal resolutions.

| **Neuroimaging Tools** | **Spatial Resolution** | **Temporal Resolution** |
|---|---|---|
| **fMRI** | High/good | Low/limited |
| **EEG** | Low/limited | High/good |
| **MEG** | High/good | High/good |
| **PET** | High/good | Low/poor |
| **TMS** | High/good | High/good |

**Figure 1. Schematic overview neuroimaging tools**

## 3.2 Non-neuroimaging techniques & tools

As mentioned above, not only the internal reflexes should be examined in order to come up with a more suitable way of applying neuromarketing. External reflexes should be examined as well to make a study more valid. The methods of analyzing external reflexes are not new. Among these methods are facial coding, eye tracking and galvanic skin response (GSR). These methods will be described in this section.

### *3.2.1 Facial Coding*

Facial coding is a method that connects emotions to body language, in particular facial expressions. This method is applicable when a subject is subjected to a marketing stimulus and where you want to know the response of this stimulus. When someone is subjected to an advertisement, their facial expressions will be recorded. Thereafter, the data will be analyzed and linked. During such an experiment, those recordings can show which parts of the advertisement provokes emotions (Postma, 2014). The disadvantage of this method is that the subject is aware of the fact that he or she is being recorded in order to know their facial expressions to the stimulus. This method alone is not suitable when it is not combined with other external methods or neuroimaging methods like fMRI.

### *3.2.2 Eye Tracking*

Eye tracking can be used for judging for example advertisements, logo's and webpages. It can record what people see, what they don't see, where their attention is heading and even the sequence can be shown. The recorded data will be collected and often a heat map will be made. A heat map shows what the eye saw, what it did not see and for how long (Postma, 2014). Eye tracking has often been used in combination with EEG. A research, which combined EEG and eye tracking, showed for example that when the participants required to choose their preferred cracker, described by shape, flavor and topping, that the flavors and toppings of the cracker were more important than the shape of it. They used an eye tracking system to relate the data acquired by EEG to the specific choice options (crackers) (Khushaba, et al.,

2013). Nowadays, a method like eye tracking reached a highly sophisticated standard and is a very interesting tool for applications in academic research such as consumer neuroscience. However eye tracking is limited, because it cannot be assured that the visual information was actually subjected to mental processing. When eye tracking is simultaneously used with neuroimaging techniques such as EEG or fMRI, it would be possible to determine which areas of the visual field of the subject are actually in the focus of conscious processing (Koller, Salzberger, Brenner, & Walla, 2012). In a study they investigated the role of stimulus-driven and goal-driven control in saccadic eye movements, a fast eye movement to find a new point of fixation. The results showed that fast eye movements were driven by (salient) stimuli in which the subjects were subjected to. In general, the subject or decision maker is biased when salient features are added (Van Zoest, Donk, & Theeuwes, 2004). Thus when salient features are added to packaging for example, it will attract the attention of the decision maker and can thereby influence their consumer behavior.

#### *3.2.1.1 Galvanic Skin Response*

The Galvanic Skin Response (GSR) is an electro dermal response. Those electro dermal responses are changes in the electricity of a person's skin. These can be caused by the interaction between external events and the physical & psychological state of the particular person. The skin of a human being is a good conductor of electricity and when a person is attached to a GSR appliance and when a certain voltage is applied, the GSR can be picked up and visualized (Muller, et al., 2013). Just like eye tracking, GSR should be use simultaneously with neuroimaging techniques and is therefore often used in combination with EEG. A study on skin care product advertisement showed the added value of combining different neuroimaging methods and GSR. They tested whether neurophysiological measure can detect differences in the reactions of consumer when they are subjected to different marketing stimuli. By using EEG, EMG and GSR, they were able to detect significant differences in neurophysiological reactions to an altered scene. When EEG is combined with GSR, or some other skin conductance measurement, it can enable to determine the intensity as well as the direction of the arousal (Ohme, Wiener, Reykowska, & Choromanska, 2009).

## 3.3 Combination of neuroimaging tools and non-neuroimaging tools

In section 2.1 different neuroimaging tools and in section 2 different non-neuroimaging tools have been explained. All of these neuroimaging tools have their strengths and limitations. Some have good temporal resolution, while others have good spatial resolution. fMRI has a good spatial resolution, while the temporal resolution is relatively poor. MEG scores very well on temporal resolution (milliseconds), while it scores poor on spatial resolution. The scores of EEG on spatial and temporal resolution can be compared to the scores of MEG. But MEG performs better when activity in the deeper structures of the brain need to be visualized (Kenning & Linzmajer, 2010). The spatial resolution of PET is relatively high (3-6mm), while the temporal resolution is very low (several minutes). TMS scores relatively good on both resolutions, however it can only measure the activity of the cortical areas close to the skull (Kenning & Linzmajer, 2010). So each of these neuroscientific tools have its strengths and limitations and combining two or more neuroimaging tools can benefit, amplify and improve the validity of research findings. However, not all neuroimaging tools can be combined simultaneously. EEG can be combined with fMRI for example (Kenning & Linzmajer, 2010). Since fMRI and EEG complement each other on their temporal and spatial resolution, Debener et al. (2006) proposed that when these two tools are combined, the recordings on a single-trial level enables the temporal dynamics of information processing to be characterized within spatially well-defined neural networks (Debener, Ullsperger, Siegel, & Engel, 2006). In other words, they combined a good spatial resolution from the fMRI with the good temporal resolution of the EEG. TMS could for example be combined with either fMRI or EEG. However there is no general neuroimaging tool that should be combined with TMS. Since each neuroimaging tools have their own strengths and weakness, the combination should depend on the scientific question, whereby the aspects of neuronal function are captured by a given neuroimaging tool together with the spatial and temporal resolution should be taken into account (Siebner, et al., 2009). The simultaneous use of two different neuroimaging tools could enable to answer novel questions which could not be answered with either one neuroimaging tool or when two neuroimaging tools are used at separate times (Kable, 2011). In order to improve the validity of research findings, non-neuroimaging tools could also be combined simultaneously with neuroimaging tools. Eye tracking for example, can be combined with EEG or fMRI. Thereafter it would be possible to determine which areas of the visual field of the subject are actually in the focus of conscious processing (Koller, Salzberger, Brenner, & Walla, 2012). Just like eye tracking, GSR can be used simultaneously as well with EEG or EMG. When it is combined with EEG, it will be able to determine the intensity as well as the direction of the arousal (Ohme, Wiener, Reykowska, & Choromanska, 2009). In another study they combined EEG simultaneously with GSR and heart rate in order to measure both brain activity and the emotional engagement. No differences between the level of GSR rates were observed, however they observed increased heart rates and the cerebral activity in the brain (Vecchiatio, et al., 2010). Neuroscientific methods differ. Some methods test the association between brain activity and behavior, while others test the necessity of brain activity of behavior, or the sufficiency of brain activity for behavior (Kable, 2011). Combining different methods would improve the research and therefore the methods should be combined that can address questions of association, necessity and sufficiency (Kable, 2011). This statement is supported by Plassmann et al. (2012) and Kenning & Linzmajer (2010). Plassmann et al. (2012) also conclude that when different tools from the neuroscientific toolkit are combined, it will be able to establish brain behavior relationships that are meaningful for understanding psychology underlying consumer choices and preferences (Plassmann, Ramsøy, & Milosavljevic, 2012). As mentioned above, each individual neuroscientific tool has its weaknesses and strengths. Therefore, combining two or more could improve the validity of research findings (Kenning &

Linzmajer, 2010). Today, neuroscientific findings can be called preliminary, not concluding and in general not converging. Because of this, the validity of these research findings should be increased with the help of combining neuroimaging tools with other neuroimaging tools or non-neuroimaging tools.

## 4. NEUROSCIENTIFIC FINDINGS

In this section, neuroscientifc findings will be reviewed for applicability by scrutinizing neuroscientific literature. The question that will be answered in this section is: Which neuroscientific findings have been published that are applicable for use and can the proposed framework from consumer neuroscience be used for neuromarketing? Next to the answers for these questions, an overview will be shown to point out the contributions from neuroscience to consumer neuroscience and neuromarketing.

Aforementioned, it is undeniable that neuroimaging has the power to contribute existing scientific techniques, tools and frameworks (Javor, Koller, Lee, Chamberlain, & Ransmayr, 2013). Neuromarketing will eventually or already help marketers to examine consumers in ways that bypass the potentially deceptive character of their conscious and controlled responses (Andrejevic, 2012). The amount of advertisement a person is exposed to on a day is enormous, so the powerful appeal of neuromarketing is that its alleged power is to cut through the clutter that marketers themselves have made (Andrejevic, 2012). Andrejevice (2012) described it as follows: bodily responses are promised to provide a level of accuracy that the words of consumers and conscious thoughts could not. This statement is affiliated with the redesign for the Campbell's label. The Campbell Soup Company is a very known brand in the United States and they brought in neuromarketers to help them redesign its label. The neuromarketers used a diverse toolkit, for example heart rate, galvanic skin response (GSR), eye tracking and facial coding, to come up with a new label. When the new label was being released, an article in the Wall Street Journal dedicated to the use of neuroscience to come up with a new label, boosted the visibility of neuromarketing, created a hype and helped the promotion of its new label (Andrejevic, 2012). As mentioned before neuroscientific tools have its strengths and limitations, combining two or more would benefit research findings. It will validate the research. However, not all neuroimaging tools can be combined simultaneously in the same research. In order to make the research a more valid one, one could combine neuroimaging tools with non-neuroimaging tools.

At this point in time, it is very important to classify findings from consumer neuroscience specific to this field. A framework, proposed by Solnais et al. (2013) will help to clarify the current state of the consumer neuroscience findings by linking results between different studies and it will also draw a more precise boundaries of the scope of consumer neuroscience (Solnais, Andreu-Perez, Sánchez-Fernández, & Andréu-Abela, 2013). A framework like this is not only useful for classifying the current state of consumer neuroscience, it is also useful for future studies. However, this framework is a very new one and not definite. Since it is not definite, future studies should be able to confirm this framework or propose a new one. Since no other frameworks have been proposed, except the one from Plassmann et al (2012) the framework by Solnais et al. (2013) will be used to check whether the contributions of neuroscience to consumer research contributes to neuromarketing. The framework proposed by Plassmann et al. (2012) is used to integrate previous consumer neuroscience studies that are directly related to branding questions (Plassmann, Ramsøy, & Milosavljevic, 2012). Therefore, this framework will not be used because it is only related to branding questions, while the framework from Solnais et al. (2013) is a more broader view on the contributions of neuroscience to consumer neuroscience. However, there is consistency and overlap between the two frameworks. By linking and or comparing results between different studies a more external valid state will be obtained. External validation is the process of testing the validity of a measure, by examining or testing its relationship to other indicators of the same variable (Babbie, 2010). Thus, if the results correlate between different neuroscientific studies and if these results are categorized, a more external valid state will be gained.

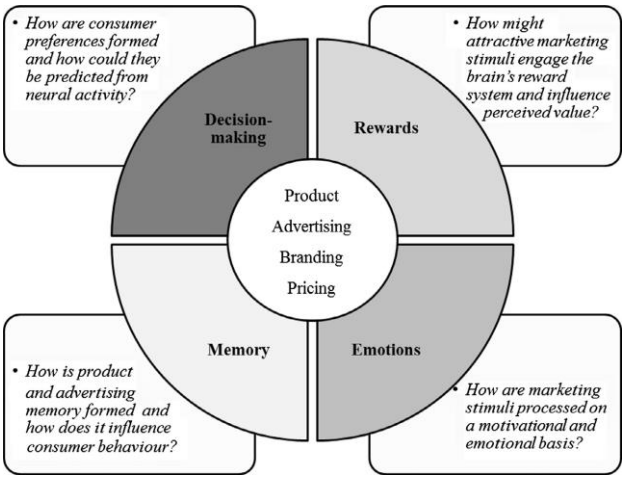


**Figure 2. Conceptual framework for assessing the contribution of neuroscience to consumer research** (Solnais, Andreu-Perez, Sánchez-Fernández, & Andréu-Abela, 2013)**.**

This framework consists of four core categories based an empirical review on collections of studies done by Solnais et al. (2013). Each category is formed by collecting the empirically tested variety of marketing stimuli. These stimuli are displayed in the center of the framework (Product, advertising, branding & pricing). The first category is consumer decision making and the formation of consumer preferences. The question raised in this category is how preferences of consumers are formed and how they could be predicted when using neuroimaging techniques such as fMRI, MEG and EEG. The second category is about the influence of the attractiveness of marketing stimuli on the brain's reward system and how these marketing stimuli influences the perceived value experienced by consumers. The third category emphasis the emotional and motivational neural responses to marketing stimuli endured by consumers. The fourth and last category is how the attention and memory of consumers are founded when marketing stimuli are applied and how these neural foundations of attention and memory influences the behavior of consumers.

Since this proposed framework in Solnais et al. (2013) applies to consumer neuroscience, it is questionable whether it is applicable for neuromarketing. Interesting neuroscientific findings started providing evidence on how marketing stimuli engages the reward system of the brain and relatively few on the consumers motivational & emotional responses, respectively category 2 and 3. Thus further research and evidence is needed to confirm or even reject these findings. In order to add validity to a category,

more evidence from other research that supports this category should be added. In category 3 Solnais et al. (2013) consumers' emotional responses and motivational tendencies are central. They propose that consumer neuroscience has provided relatively few answers so far as there is little evidence of the activation of brain areas during the processing of non-rational advertising messages (Solnais, Andreu-Perez, Sánchez-Fernández, & Andréu-Abela, 2013). However, Bechara & Damasio (2005) showed that emotions are a major factor in the decision-making process. On the other hand, this does not necessarily mean that more validity is added to category 3. Further research on this topic need to achieve a more valid state. Due to the fact that sufficient evidence is missing for these categories, it cannot be used for application in practice yet and therefore not for neuromarketing. However, consumer neuroscience started providing converging evidence related to the decision making process in the brain (category 1) and it started providing sufficient findings in relation to consumers' memory and attention (category 2) (Solnais, Andreu-Perez, Sánchez-Fernández, & Andréu-Abela, 2013). Thus when findings are worthwhile, such as the findings for category 1 & 4, than they may or can be able for use in practice and therefore suitable for neuromarketing. Concluding, findings for this framework started providing evidence, however there is no confirmation yet for all categories. As a result of this, applicability is missing and thus in general, this framework contributes to consumer neuroscience, as well as for consumer research, but not for neuromarketing.

Neuroscientific research started providing converging evidence for category 1 & 4, respectively the decision-making process and the foundation of attention and memory. An example for the first category is that emotions influences the decision-making process. According to modern economic theory, human decision-making is a rational process where humans are equipped with unlimited knowledge and where emotions are ignored. This theory contradicts a study done by Bechara & Damasio (2005) where they concluded that emotions are major factor in decision-making as opposed to the construct of homo economicus (Bechara & Damasio, 2005). Kenning & Linzmajer (2010) support this study by stating that at this point research has shown that consumers cannot be seen as completely rational in the decision-making process due to the fact that emotions and unconscious processes are playing a central role in generating behavior (Kenning & Linzmajer, 2010). At the center of the framework proposed by Solnais et al. (2013) different marketing stimuli are presented (product, pricing, etc.). A study, done by Plassmann et al. (2008), showed an example of a contribution from neuroscience to marketing research. Neural representations of expected pleasantness can be influenced by marketing stimuli or marketing actions, such as change in price of a particular product. They tested this insight by using fMRI while subjects tasted wines. These wines however, were believed to be different and sold at different prices as the subjects thought. The results showed that when the price increased, the subjective reports by the subjects on flavor pleasantness increased as well. Not only these subjective reports contributes to the insight that marketing actions influences expected pleasantness. Also the images from the fMRI scans contributed to this insight. The images showed BOLD activity in the area of the brain which is widely thought to encode for experienced pleasantness (Plassmann, O'Doherty, Shiv, & Rangel, 2008). In the fourth category is about consumers' attention and memory. Attention is the mechanism responsible for selecting the information that gains preferential status above other available information (Plassmann, Ramsøy, & Milosavljevic, 2012). A recent study on attention and the following decision making, showed that salient features of food packaging, for example brightness and highlights, influence the decision making for food choices. They have used an experimental design from visual neuroscience and in particular an eye-tracker to obtain data. The study showed that when the food packaging of items were brighter, fast decisions were made in advantage of the items with brighter packaging even when the subjects preferred the taste of the alternative items with less bright packaging (Milosavljevic, Koch, & Rangel, 2012). Thus far, the proposed framework for assessing the contribution of neuroscience to consumer research cannot be used for neuromarketing due to the lack of general converging evidence. However, some neuroscientific findings do support some of it, though it is not sufficient enough to contribute to neuromarketing yet. Above the contributions from neuroscience to consumer neuroscience and consumer research have been pointed out. A framework like the one from Solnais et al. (2013) is a clear tangible contribution from neuroscience to consumer neuroscience and vice-versa. Neuroscience, in particular neurology, benefits from the results of consumer neuroscience and neuromarketing. Consumer behavior, or general behavior, has always been of particular interest in neurology (Javor, Koller, Lee, Chamberlain, & Ransmayr, 2013). Therefore consumer neuroscience enables neurology to obtain a more comprehensive understanding of human behavior (Javor, Koller, Lee, Chamberlain, & Ransmayr, 2013). In other words, it is a trade-off between consumer neuroscience and neurology. Not only consumer neuroscience contributes to neuroscience, also the collaboration between economists and marketing researchers, in particular neuromarketing, contributes to neuroscience and vice-versa since the neurobiology of behavior is a major topic in the neurological community (Javor, Koller, Lee, Chamberlain, & Ransmayr, 2013). The reason why it is of particular interest in neurology, is that research findings suggests that behavioral symptoms of neurological diseases could affect economic decision-making and consumer behavior (Javor, Koller, Lee, Chamberlain, & Ransmayr, 2013). Below a simple schematic overview of the contributions from neuroscience to consumer neuroscience, neuromarketing and vice-versa.

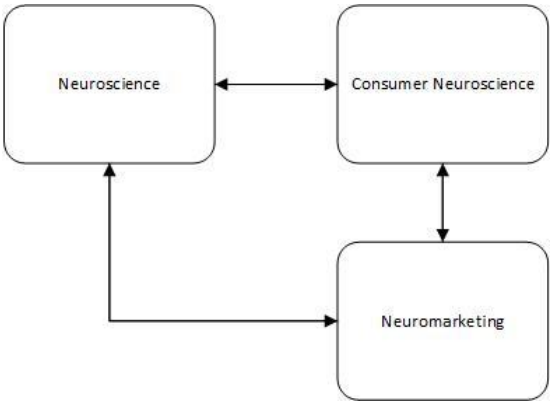


**Figure 3. Schematic overview of the contributions**

The problem for neuromarketing and consumer neuroscience is the issue of reverse inference. It means that it reasons backwards from activation of a particular area in the brain to the connection of a particular cognitive function (Poldrack, 2006). The problem of reverse inference still exist due to the fact the functional brain imaging research is still in its infancy, or relatively new, and yet there is no detailed map of the brain available for use and the fact that a certain area of the brain includes possible more mental processes (Plassmann, Ramsøy, & Milosavljevic, 2012). Plassmann et al. (2012) raised the flag of this issue of reverse inference mentioning that it becomes very problematic when the central findings of a paper are built on reverse inference. Poldrack (2006) speaks of a true epidemic taking the following form. (1) In a study when task comparison A was presented, area Z in the brain was active. (II) In other studies, when cognitive process X was expected to be engaged, then brain area Z was active. (III) So the cognitive process X can be connected with the task comparison A. Below a simple schematic overview of the contributions from neuroscience to consumer neuroscience, neuromarketing and vice-versa will be shown with the reverse inference implication.

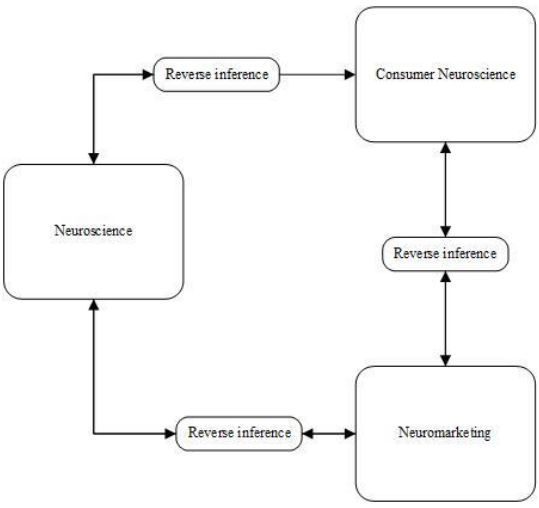


**Figure 4. Schematic overview of the contributions with the reverse inference implication.**

## 5. CONCLUSIONS & RECOMMENDATIONS

When different neuroimaging tools would be combined with other neuroimaging tools or non-neuroimaging tools, it could improve neuroscientific research. It could establish brain behavior relationships in order to understand consumer behavior and it could also reveal the underlying preferences of consumers. However, the problem for neuromarketing researchers is the issue of reverse inference. This implies reasoning backwards from activation in particular brain area to the connection of cognitive process or function. The problem of reverse inference still exist due to the fact the functional brain imaging research is still in its infancy, or relatively new, and yet there is no detailed map of the brain available for use and the fact that a certain area of the brain includes possible more mental processes. However, it is possible to infer with confidence that when a cognitive process is engaged with the activation in a particular area of the brain, when a specific area of the brain is activated relatively selectively by a specific cognitive or mental process. In other words, confidence in the research finding will increase when a particular area of the brain is activated relatively selectively by a specific cognitive process of interest. Combining methods as mentioned above, could also help establishing more substantial confidence in finding the particular process which is engaged, giving the activation in the particular part of the brain. Findings for the framework opposed by Solnais et al. (2013) started providing evidence, however there is no confirmation yet for all categories. As a result of this applicability is missing and thus in general, this framework contributes to consumer neuroscience and not neuromarketing. Figure 3 and 4 shows the contributions, in simple schematic overviews, of neuroscience to consumer neuroscience, neuromarketing and vice-versa. The framework opposed by Solnais et al. (2013) is clear example of the contribution from neuroscience to consumer neuroscience and vice-versa. However, the results are preliminary, not concluding and there is a lack of general converging evidence. Consumer behavior has always been of interest in neurology and therefore the contribution of consumer neuroscience to neurology is clear since neurology can benefit from the research findings. Not only benefits neurology from consumer neuroscience, it also benefits from the collaboration between economists and marketing research, in particular neuromarketing. It is of interest for neurology because research findings started providing evidence that economic decision-making and consumer behavior could be affected by behavioral symptoms of neurological diseases.

## 6. LIMITATIONS

The problem for neuromarketing researchers and neuromarketing practicers is the issue of reverse inference. The problem is the proposed one-on-one relationship between the brain activity and the mental process of interest (Plassmann, Ramsøy, & Milosavljevic, 2012). It means that it reasons backwards from activation of a particular area in the brain to the connection of a particular cognitive function (Poldrack, 2006). The problem of reverse inference still exist due to the fact the functional brain imaging research is still in its infancy, or relatively new, and yet there is no detailed map of the brain available for use and the fact that a certain area of the brain includes possible more mental processes (Plassmann, Ramsøy, & Milosavljevic, 2012). Plassmann et al. (2012) raised the flag of this issue of reverse inference mentioning that it becomes very problematic when the central findings of a paper are built on reverse inference.

For all limitations there is a solution. If a region in the brain is activated by a large number of mental processes, then activation in that area of the brain provides relatively weak evidence of the engagement of a mental process. This due to the fact of reverse inference and that one area of the brain is usually involved in more than one mental processes (Plassmann, Ramsøy, & Milosavljevic, 2012). When a specific area of the brain is activated relatively selectively by the specific mental process of interest, then it is possible to infer with substantial confidence that the particular process is engaged given the activation in that area (Plassmann, Ramsøy, & Milosavljevic, 2012). So when more research starts providing conclusions that a specific area of the brain is activated by the mental process of interest, it will add validity and confidence in the engagement of the activation in that area. Another possible solution is that mining of neuroimaging databases can proved insides into the strength or weakness of specific inference from neuroimaging data. However the use of these databases are limited due to coarseness of the underlying ontology used (Poldrack, 2006). In other words, people use different words and definitions.

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