2018

**Yasin Genc**

# The use of fMRI in consumer psychology

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Tese apresentada ao IADE – Universidade
Europeia, para cumprimento dos requisitos necessários à
obtenção do grau de Mestre em Marketing
realizada sob a orientação científica do Professor João Pedro Lucena.

I dedicate this thesis to all who have been wondering why I buy things

**the jury**

president Prof. João Pedro Lucena

professor do IADE – Universidade Europeia

**acknowledgments**

I wish to express my sincere gratitude to everyone who dedicated for  realization of this dissertation especially my wife Yasemin

## abstract

Consumer Neuroscience presents Marketers with the challenge of dealing intensively with the multitude of neuroscientific topics and methods. This area is becoming very important as consumers interests are changing. In order to be able to analyse questions of consumer behavioural research from a neuroscience perspective, knowledge about the application of functional magnetic resonance imaging (fMRI) is extremely valuable. However, methodological problems in connection with the fMRI are not sufficiently discussed in the Marketing area. Under this perspective, the central aim of the present work is to present concrete strategies for empirical investigations using the fMRI and to discuss the characteristics, advantages and disadvantages of these options, taking into account already existing research designs. On the one hand of this scientific work theoretical and conceptional reviews of the fMRI and on the other hand empirical fMRI studies are evaluated. Only publications that are marked as A + or higher Journals are considered in this research. First, the results of the literature research show a noticeable increase in the use of event-related designs. Second, it can be seen that only a fraction of the fMRI respondents have a sufficiently large sample size. Third, it is likely that the analysis of fMRI data will become more complex and therefore continue to be the main challenge in conducting an fMRI study.

**Keywords:** *fMRT, consumer neuroscience, consumer behaviour, neuroscientific measurement methods*

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# 1. Introduction

The first chapter is an introduction to the problem and the resulting research question. Afterwards I will describe the methodical procedure for answering the research question as well as the structure of the work.

## 1.1. Relevance of the topic and problem definition

According to the Global Pricing Study of the strategy consultancy Simon-Kucher & Partners (2014), 72 percent of all new products fail in the market. The failure of these products is due to the fact that with the traditional market research methods, sometimes motives and preferences of consumers cannot be adequately determined. As a consequence, companies impose incorrect prices for new products and emphasize a wrong value for new products or introduce low-attractiveness products into the market (cf. Evanschitzky, Eisend, Calantone & Jiang, 2012, p.29; Simon-Kucher & Partners, 2014). To avoid such mistakes in the innovation process, research must correctly identify all consumer needs. For example, consumer goods manufacturer Unilever financed a functional magnetic resonance imaging (fMRI) study that examines the effect of the human brain on the expectation for a certain food (see Woods et al., 2011, p. 265).

On the other hand Daimler AG already demonstrated a decade ago how different the brain reacts to the presentation of vans, sports cars and small cars. The growing interest in neuroscientific methods and findings also benefits the consulting and market research industry. There are now around 120 market research institutes worldwide that apply brain research to their customers questions (see Nuwer, 2014, Olteanu, 2014).

Specialist as well as public media respond ambivalently to studies in which neuroscientific measurement methods are used for market research purposes. On the one hand, methods such as the fMRT are touted, as a window to the human brain, which allows to reach inside a buyer (Kaufman, 2010) and there the "Brain's Buy Button". Market research experts complain that agencies hardly deal with theories and methods of neuroscience. Some neuromarketing providers failed to interpret fMRI data because they lack on knowledge of cognitive and emotional psychology approaches (see Esch, 2013, p. 33; Scharrer, 2013, p.45). According to a representative of the German market research industry, science is necessary in order to finally create standards for customers (see Scharrer, 2013, p.23). Vice president of US market Allan Fromen (2014) says that methodological competence is an important starting point for establishing the fMRI in marketing practice: "We need to marry our excitement with methodological and academic rigor, to put our clients at ease and help inform the industry ". Overall, the cited voices show that market research firms should not underestimate the strategic importance of neuroscience methodological competence.

At the same time, it is also demanded in the academic context that marketing scientists and consumer behavioural researchers deal intensively with the multitude of neuroscientific theories, fields of application and methods (Poldrack, 2012, p. 1216-1217). For example, Achrol and Kotler (2012, p. 51) strongly support the acquisition of "expertise in fMRI". However, the systematic analysis of relevant marketing scientific journals[1] shows that theoretical and methodological questions in general and in connection with the fMRI are rarely discussed. In total, four theoretical-conceptual works could be identified.

As illustrated in Table 1, three of the four identified contributions focus on more general methodological challenges confronting consumer neuroscience. For example, the problem of inverse consequences ("reverse inference")[2] is discussed. In addition, applications of the still young field of research Consumer Neuroscience are outlined. In addition, new research perspectives are opened (see Huettel & Payne, 2009, pp. 14-16). Only the work of Yoon, Gonzalez and Bettman (2009) deals explicitly with methodological aspects of planning and conducting fMRI studies. Specifically, recommendations are made regarding research design, experimental design, and interpretation of fMRI data (see Yoon et al., 2009, pp. 17-19).

[1] In the evaluation, only journals that are rated A + or A in the marketing sub-ranking of VHB-JOURQUAL 3 were considered.

[2] See the comments on reverse inference in Section 4.5.2.

| | authors | publication in | main topics |
|---|---|---|---|
| Consumer Neuroscience | Huettel/Payne (2009) | Journal of Marketing Research | - neuroscience vs. behavioral science<br>-methodical challenge of reverse inference<br>- convergence of neuroscience and behavioral science research |
| | Plassmann/Ramsøy/ Milosavljevic (2012) | Journal of Consumer Psychology | - concrete application of consumer neuroscience in market research<br>- methodological challenges of consumer neuroscience<br>- future outlook |
| | Plassmann/Venkatraman/ Huettel/Yoon (in Druck) | Journal of Marketing Research | - application areas of consumer neuroscience in marketing<br>- methodical challenge of consumer neuroscience<br>- future outlook |
| fMRT | Yoon/Gonzalez/Bettman (2009) | Journal of Marketing Research | - methodological challenges of fRMT studies, in particular: research concept; experimental design; data interpretation |

Table 1: Theoretical conceptual work published in A + and A journals on methodological aspects of consumer neuroscience and fMRI

The remarks in this section shows that, in addition to science, practitioners are also interested in such papers that shed light on methodological problems associated with fMRI studies. However, methodological issues in marketing research have been insufficiently discussed so far. In particular, there are no contributions that do not remain abstract with regard to the design of fMRI studies, but it rather shows concrete design options for empirical studies and discuss the advantages and disadvantages of these options. The present work aims to help deepen the methodological discussion.

### 1.2. Objective and methodical approach

The aim of the present work is to show concrete options for the design of empirical investigations by means of the fMRI, taking into account existing research designs[3].

[3] In the present work, according to Savoyvthe term research design means not only the conception of the experimental design of an empirical investigation by means of the fMRI, but also the collection, analysis and interpretation of the fMRI data (see Savoy, 2012, p.1204).

This results in the following research question:

• Which design options are there to realize an empirical investigation using the fMRI in consumer behavioural research?

To answer this research question, two sub-questions are formed, which will be discussed in this thesis. The sub-questions focus on the structure and design of empirical investigations by means of the fMRI as well as on their design:

• Which process steps does an empirical investigation by the fMRI include?

• Which research designs are used in the fMRT for researching consumer behavior in Marketing?

In order to clarify these questions, theoretical reviews of the fMRI must be analysed, secondly empirical fMRI studies must be analysed. All empirical studies reviewed were published from 2010 to 2015 in high-profile marketing journals and in neuroscientific journals. The evaluation of the theoretical contributions, however, is not limited to a specific publication period. However, only publications that are marked as A + and Jornals with high impact factor were used for this research. Furthermore, only empirical studies are evaluated which examine the psychological processes relevant to consumer behavioral research.

### 1.3. Construction of the work

The present work is structured as follows: The First chapter is the introduction, the second chapter will examine consumer behavioral research from a neuroscientific perspective. First of all, the theoretical fundamentals of consumer behavior are clarified. The focus is on those mental processes that serve as constructs for describing and explaining consumer behavior. The merging of consumer behavior research and neuroscience into the new research direction of consumer neuroscience is also part of the second chapter. Particular attention is paid to those neuroscientific measurement methods that can complement traditional behavioral observation and measurement.

The third chapter explains the fMRT with the presentation of the physical basics of the fMRI and is followed by a short discussion of the strengths and weaknesses of this particular process. The chapter concludes with an overview of the most important methodological steps that are taken in the conception and execution of an investigation using the fMRI. Specifically, the essential aspects of the structure and design of investigations using the fMRI are examined in more detail.

Building on this, the fourth chapter will show to what extent the different design options of empirical fMRI research are used. To clarify this question, study designs of current fMRI studies are analyzed, compared and evaluated. Based on the process steps of empirical investigations in Chapter 3, the manifold design options are systematized. Design options are discussed with respect to the formulation of the research question, the experimental design, the subject selection, the data analysis and, finally, the interpretation of the fMRI data.

The most important findings of the work are summarized and the implication for research are also revealed in the fifth chapter.

## 2. Consumer behaviour research from a neuroscience perspective

The first chapter showed that the integration of neuroscientific methods into marketing has become more important than ever. We can ask the question why consumer behavior research is in close collaboration with biologically-oriented neuroscience? This question is answered in the second chapter of this thesis. The focus is on the notion of unobservable mental processes inside the consumer. This will provide the theoretical foundation needed to understand consumer neuroscience. This young field of research, which investigates the psychic processes inside the consumer by means of neuroscientific knowledge and methods, is described in Section 2.2.

### 2.1. Theoretical basics of consumer behaviour

Figure 1 illustrates the structure of this section: First, the beginning of consumer behavior research are outlined and the concept of consumer behavior is defined (see Section 2.1.1.). This is followed by the presentation of the stimulus-organism-response (S-O-R) model (see Section 2.1.2.). Finally, the psychic processes of consumer behavior are examined in more detail (see Section 2.1.3.).

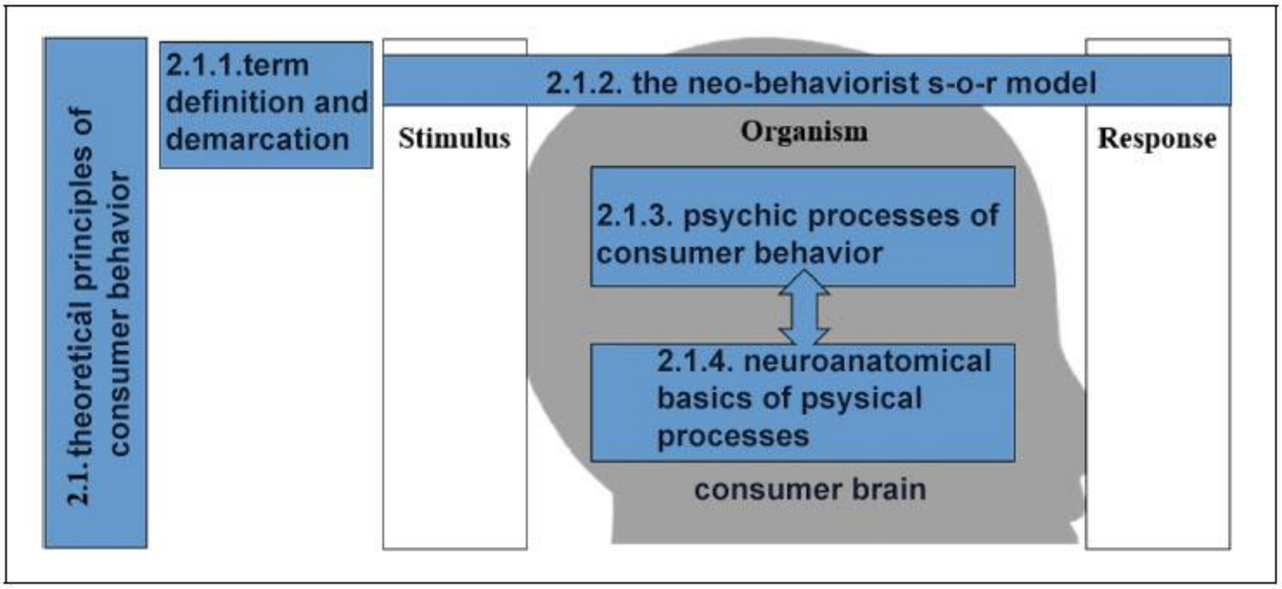


**Figure 1**: Structure of the section 2.1

### 2.1.1. Definition of terms and demarcation

The beginning of consumer behavior research goes back to the USA of the 1920s (see Kroeber-Riel & Gröppel-Klein, 2013, p.34). However, the real breakthrough in Anglo-American research came after World War II, when there was a tremendous increase in scientific publications and conferences on consumer behavior (see Clark, 1955, Howard & Sheth, 1969, Kassarjian & Robertson, 1968). In Europe, institutionalization of consumer behavior research did not take place until the 1970s.

There are many definitions of consumer behavior in the literature. Publications from the 1960s (see MacInnis & Folkes, 2010, p. 900) show that consumer behavior was initially understood solely as buyer behavior: For example, Howard and Sheth (1969, p. 30) provided an important explanation for the buying behaviour of buyers with their total model. The same applies to the comprehensive model of Engel, Kollat and Blackwell (1968, p. 34), which describes the individual phases that ultimately lead to a purchase decision.

For example, Kuss and Tomczak (2007, p. 12) understand consumer behavior as the "selection of one of several offers of goods, services, rights and assets by individuals, groups and organizations, including those leading to this decision and of that decision following processes and activities that may affect future purchases ". The first part of the definition indicates a relatively narrow perspective, which is purely based on the purchase decision. In the second part of the definition, however, the authors expand their perspective by explicitly paying attention to the pre- and post-purchase processes.

Foscht and Swoboda (2011, p. 3) also focus on the act of purchase in their definition, but have a more general understanding of terms than Kuss and Tomczak. They describe consumer behavior as "behavior of end consumers in the purchase and consumption of economic goods and services" (Foscht & Swoboda, 2011, p. 3). The two authors completely hide pre-emergence processes. In addition, they only understand the consumption of goods and services under post-purchase processes.

A broader understanding of consumer behavior is gaining in importance as more and more publications are published that discuss, for example, sustainable consumption. (see Belk, 2013, Jerath, Ma & Park, 2014). Kroeber-Riel and Gröppel-Klein (2013, p. 3) tried to do justice to this development by distinguishing between consumer behavior in the narrower sense and in the wider sense: "Consumer behavior in the narrower sense means the observable, external" and the unobservable 'inner' behavior of people in the purchase and consumption of economic goods. In the broader sense also the behavior of voters, museum visitors or patients ".

The aim of this work is to present which options can be chosen in the design of an fMRI study in order to optimally map relevant mental processes. Therefore, makes sense to have a close understanding of consumer behavior that focuses on the unconscious processes in the consumer's brain that determine it in its buying decision process. For Kroeber-Riel and Gröppel-Klein (2013, p. 3), consumer behavior is understood to be observable external reactions and unobservable internal reactions of consumers that lead to a purchase decision.

With the aim of modeling the complex processes involved in the purchasing decision process, research has developed numerous models to explain consumer behavior. In the following section 2.1.2. the peculiarities of the influential S-O-R model are briefly presented. Its predecessor model, the stimulus-response (S-R) model, will also be explained in this context.

### 2.1.2. The neo-behavioural stimulus-organism-response model

The research field of consumer behavior is part of the behavioral sciences (Kroeber-Riel & Gröppel-Klein, 2013, p. 11). In particular, two behavioral science approaches are relevant to consumer behavior research: behaviorism and neo-behaviorism.

Behaviorism uses observable external reactions as a basis for explaining consumer behavior by the so-called S-R model (see Balderjahn & Scholderer, 2010, p.5, Foscht & Swoboda, 2011, p.65). The purpose of this model is to predict which response (for example purchase) to the consumer will be triggered by a particular stimulus (stimulus, such as a product's promotion). Both psychic internal processes and individual differences in the personality structure of consumers do not take into account the S-R model (see Jacoby, 2002, p.12). However, because people often react differently to the same stimuli, the S-R model falls short and is less likely to explain consumer behavior (see Foscht & Swoboda, 2011, pp. 29-30). For this reason, the S-R model only plays a minor role in consumer behavior research in contrast to the neo-behaviorist S-O-R model, which will be discussed in more detail below.

Modern consumer behavior research is characterized by neo-behaviorism. Neo-behaviorism considers not only the observable external reactions of humans but also their inner behavior. This view is expressed in the S-O-R model, which replaced the S-R model in the mid-1960s (Jacoby, 2002, p. 51). There are two different classes of variables in the S-O-R model (see Foscht & Swoboda, 2011, 29, Kroeber-Riel & Gröppel-Klein, 2013, p.

• the observable variables, which means the observable stimuli of the environment (stimuli) and the observable reactions of the consumers as well as

• the intervening variables, which is the unobservable mental processes inside the consumer.

The SOR model combines the observable and intervening variables, leading to the following assumption: A stimulus (for example, a product promotion) is first processed in a human organism (e.g. by a change of attitude) before it becomes the trigger of human purchase decision (e.g. product purchase).

The intervening variables, which are the psychic processes inside the consumer are particularly suitable for predicting future consumer behavior (see Foscht & Swoboda, 2011, p.12). They are described in Section 2.1.3.

### 2.1.3 Mental processes of consumer behavior

Kroeber-Riel and Gröppel-Klein (2013, pp. 51-55) subdivide the mental processes of consumers into

• Activating processes, such as emotion, motivation and attitude, and

•Cognitive processes, such as information acquisition, perception, learning and memory.

Activation is the basis of all activating processes (see Foscht & Swoboda, 2011, p.43). Activation refers to the state of arousal of an individual and provides information about how powerful and efficient a human organism is. A distinction is made between tonic and phasic activation.

Whereas tonic activation refers to the general alertness of an individual, phasic activation refers to short-term activation triggered by certain environmental stimuli (see Section 2.1.2.).

Figure 2 gives an overview of how activation, which is the basic dimension of all activating processes, and the complex drives of emotion, motivation, and attitude are interrelated. Subsequently, these three central terms are briefly explained and separated from each other.

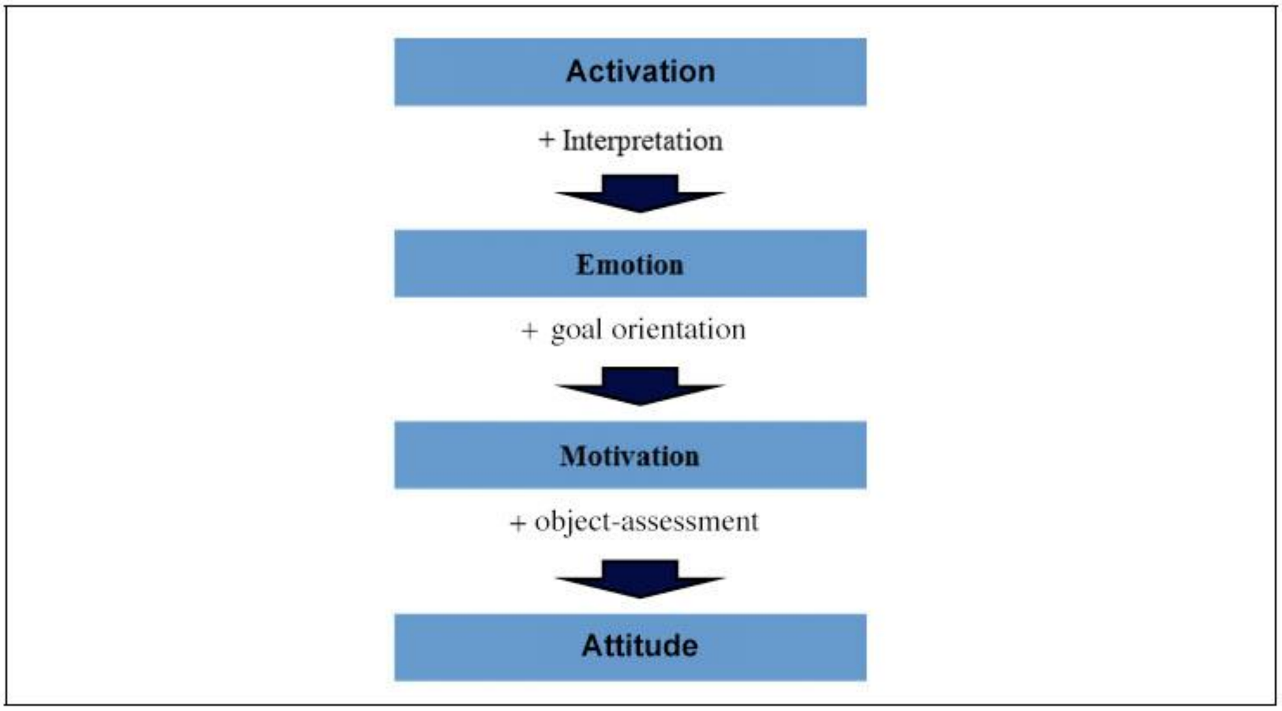


**Figure 2:** Relationship between the activating processes (based on Foscht & Swoboda, 2011, p. 37)

### Emotion

There are a lot of definition for emotion. As an example, the definition by Buhle (2014, p. 981). The author describes emotion as a process that continues over a period of time. At the beginning of the process, a stimulus hits an individual. Then the individual interprets the emotional meaning of the stimulus. This interpretation of the stimulus finally triggers an observable behavioral reaction in the individual.

Kroeber-Riel and Gröppel-Klein (2013, p. 102), on the other hand, emotion is less a process, but rather as "a subjective event, that is, an inner arousal". Izard (2007, p. 260; 2009, p. 7). A renowned representative of emotion research, further breaks down the concept of emotion into basic emotions and emotion schemes. He assumes that basic emotions are evolutionary, contain a feeling component and evoke an observable expression in the individual. These include the emotions interest, joy, sorrow, anger, disgust and fear (see Izard, 2007, pp. 261-262). In contrast, emotion schemes arise through a dynamic interaction of emotions and cognitive processes. An example of this is the emotional scheme of jealousy, which is composed of grief, anger, fear and thoughts related to these feelings (see Izard & King, 2009, p. 119). While basic emotions have their roots in evolution, emotion patterns are determined by individual differences in personality, learning, and cultural environment (see Izard, 2007, p. 261; 2009, p. 122).

Especially in saturated markets, product differentiation by means of emotions plays an important role. In this way, a product should be given an emotional value to differentiate it from other products in the market. In practice, an emotional product differentiation can be triggered by, for example, advertising for a product, packaging and design so they trigger certain feelings on the consumer (see Kroeber-Riel, 1984, p 538). The emotional stimulus should be relatively strong and often repeated.

### Motivation

Motivation is closely related to the concept of emotion. In contrast to emotion, which can be regarded as an inner emotional state, motivation leads to concrete actions (see Touré-Tillery & Fishbach, 2014, p. 328; Sokolowski, 2008, p. 311). According to this, motivation is a combination of emotion and cognitive goal orientation (see Kroeber-Riel & Gröppel-Klein, 2013, p.32).

In terms of practice, motivation is the investment of, for example, time, money and effort to achieve a specific goal (see Touré-Tillery & Fishbach, 2014, pp. 332-335). Consumer motives are satisfied by purchasing activities (see Kroeber-Riel & Gröppel-Klein, 2013, p. 206), but also by all other activities that can occur during the pre- and post-purchase phases (see also Foscht & Swoboda, 2011, p. 55). Basically, it can be stated that there are a variety of consumer motifs that can be classified differently. A widely used classification is the distinction between hedonic and utilitarian consumption motives. Hedonic consumption is used when individuals want to satisfy their need for fun, pleasure, fantasy and sensory (see Arnold & Reynolds, 2012 399; Babin, Darden & Griffin, 1994, p. 654).

**Attitude**

Third, the combination of motivation and object assessment is called an attitude (see Foscht & Swoboda, 2011, p.54). Kroeber-Riel and Gröppel-Klein (2013, p. 234, 238) argue that attitude is also among the activating processes, even though the construct has cognitive components. The authors emphasize that the attitude is primarily characterized by the emotional - positive or negative - attitude towards an object (see Kroeber-Riel & Gröppel-Klein, 2013, p. 238). Based on Fishbein and Ajzen (1975, p. 10), attitude can therefore be defined as learned emotional attitude directed to a reference object, which are positive or negative and relatively time-stable.

In contrast, the three-component theory of attitudes takes into account not just a cognitive component but also an intentional component. Furthermore, this theory assumes that all three components are coordinated. The theory is based on the assumption that every person wants to achieve a consistency of feeling, thinking and acting. Although the three-component theory is controversial in research, it nevertheless has a certain relevance with regard to the investigation of consumer behavior. Although positive affective and cognitive attitude towards a product do not necessarily result in its purchase. However, the more positive the attitude towards a product is, the higher is the purchase probability (see Foscht & Swoboda, 2011, pp. 71-72, Kroeber-Riel & Gröppel-Klein, 2013, p.78)

As mentioned at the beginning of this section, the activating process - emotion, motivation and attitude face the so-called cognitive process. The cognitive process serve the mental control and control of the human behavior, but are not clearly separated from the activating process.

The cognitive process is regarded as individual process which, give rise to the entire process of information processing. Kroeber-Riel and Gröppel-Klein (2013, p. 307) assume the following classification of cognitive process:

• Information: Information search

• Information processing: perceiving, judging

• Information storage: knowledge, learning, memory

This classification is based on the three-memory model of Atkinson and Shiffrin (1968, p. 93), which consists of the sensory memory, the short-term memory and the long-term memory. The flow of information between the stores can be described as follows (see Wentura & Frings, 2013, p.22): Incoming stimuli first enter a sensory store. Those stimuli that attract attention continue to move into the short-term memory. There the information processing takes place. Finally, only internally repeated information reaches the long-term storage in the long-term memory.

Although the three-store model has lost its relevance[4], it should nevertheless serve as a reference framework for the cognitive process described in the text below. The process of information processing can be well understood on the basis of this model, because no other model has yet been established in research that maps memory as a whole (see Kroeber-Riel & Gröppel-Klein, 2013, p. 307).

[4] According to Wentura and Frings (2013, p. 22), it is doubtful that each memory works independently of the other memories.

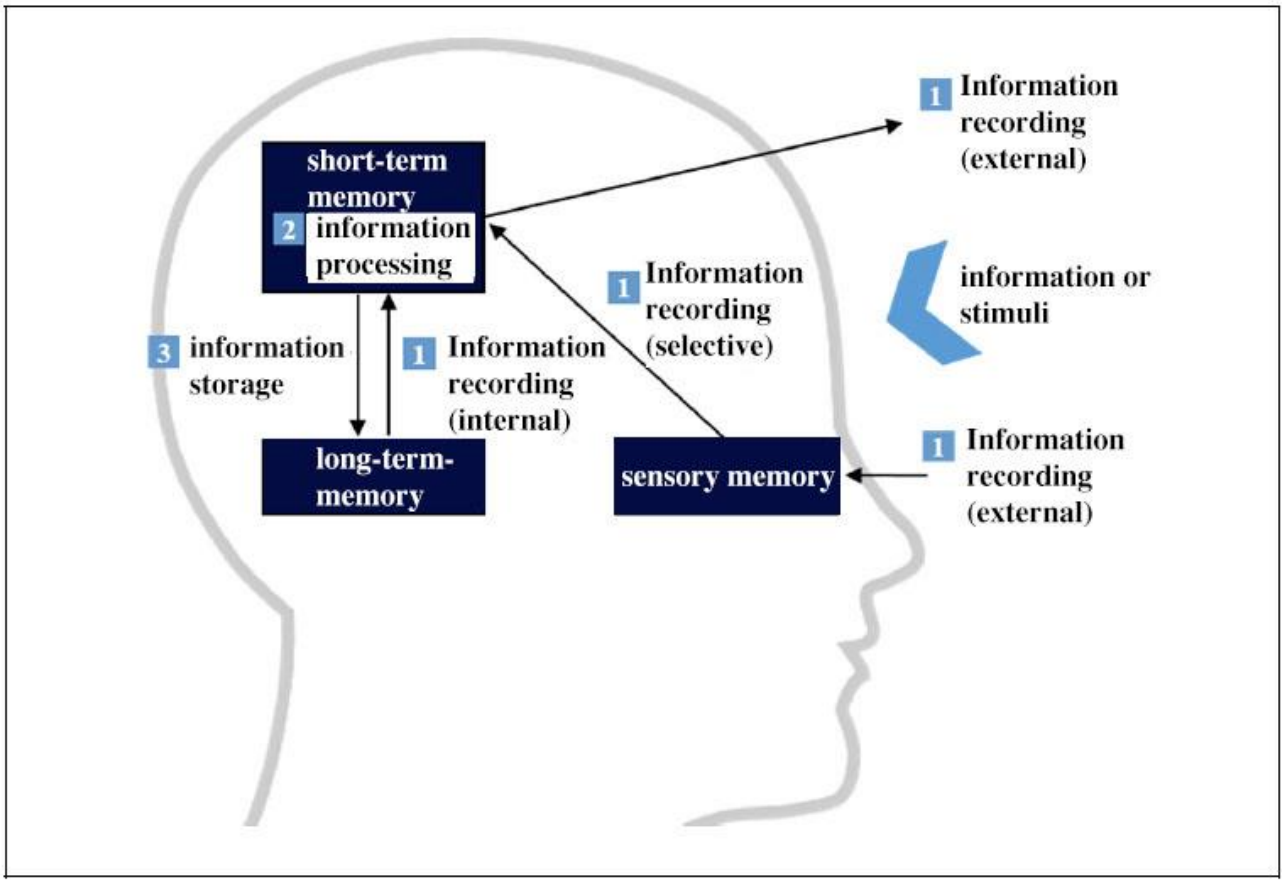


**Figure 3:** Overview of the overall process of information processing using the three-store model (Atkinson & Shiffrin, 1968, p. 93; Homburg, 2012, p. 56; Kroeber-Riel & Gröppel-Klein, 2013, p. 308)

The following Figure 3 graphically illustrates the overall process of information processing on the basis of the three-store model. Subsequently, the individual process steps of information processing are explained in more detail.

The first step in the information process consists of the (1) **information acquisition**, which proceeds as follows: First the Stimuli or information recorded by the sensory organs enter the sensory memory. There, the information is interpreted and selected. Finally, a selection of information moves to the short-term memory, where it is linked to retrieved knowledge from the long-term memory (see Kroeber-Riel & Gröppel-Klein, 2013, p 64).

There are two types of information collection: external and internal information. On the one hand, consumers can search for information through personal communication. Examples include counseling sessions and word-of-mouth propaganda by friends and family (see Haas & Kenning,

2014, p.65). Externally information gathering is for example, through mass communication, through online rating portals and through the design of the point-of-sale (see Bell, Corsten & Knox, 2011, p.31). In internal information acquisition, the consumer resorts to stored knowledge from the long-term memory. This knowledge is subconscious.

In any particular situation the consumer calls consiously it into consciousness. The internal search for information in consumer behavior is very important, since it provides information about the decision-making behavior of consumers. Every consumer makes use of previous thoughts and experiences before making a purchase decision. This means a consumer has a limited number of alternative products which he regards as positive (see Kroeber-Riel & Gröppel-Klein, 2013, pp. 472-473). If these alternatives no longer suffice him, he searches in his long-term memory for further product alternatives (see Kroeber-Riel & Gröppel-Klein, 2013, p.96)[5]. This procedure thus falls under the internal information recording. Amaldoss (2013, p. 733) examined the role of prototypical products such as Coca-Cola in the composition of the evoked set.

The information recording follows by (2) **information processing**. In this case, that information that have reached the temporary memory are decrypted. The process of information processing is characterized by Kroeber-Riel and Gröppel-Klein (2013, p. 363) as a subjective, selective and active perception process. The three characteristics of subjectivity, selectivity and activity, which characterize perception, will be briefly explained below.

In the context of information processing, the goal for a consumer is to simplify his complex environment. He succeeds by subjectively interpreting and evaluating facts, which happens very quickly. One consequence of this reinterpretation is that reality often differs from the subjectively perceived environment. Another consequence of subjectivity is that two individuals often rate the same object with same circumstances differently (see Foscht & Swoboda, 2011, p. 100).

Closely related to the subjectivity of the process of perception is selectivity. Since the sensory organs are exposed to a multitude of information or stimuli, it is necessary that a small part of relevant information is filtered out of the mass. Without filtering out the information, the sense organs would be overstrained, which in turn would make information processing more difficult (see Kroeber-Riel & Gröppel-Klein, 2013, p. 363; Pieters & Wedel, 2007, p. 225). Precondition for the perception of information is the attention. Whether a consumer's attention is high or low depends on the activation potential of a stimulus. Various studies show that emotional stimuli lead to increased consumer attention (see Nielsen, Shapiro & Mason, 2010, p. 147). Above all, emotional stimuli that trigger

[5] The terms short-term memory and working memory are used interchangeably in the following text.

surprise in the consumer have a high activation potential (see Teixeira, Wedel & Pieters, 2012, p. 156). After all, perception is an active process. The active nature of perception results from the consumer reinterpreting his complex environment in such a way that it is understandable to him. Only through analyzing of received information from the environment and inner signals it is possible for the respective person that it makes sense to him.

However, the perception is not only responsible for the decryption of information, but also for their assessment. For the consumer behavior the primare interest are brand and product assessment. Before a consumer can make a judgment on a product, it must absorb stimuli from the environment in the form of product information (color, design, price) and environmental information (design of the point of sale, sales staff). At the same time, the consumer retrieves stored information based on previous experiences with the product and its environment from its long-term memory. It develops a quality judgment in the memory from the processing of the current and the stored information (see Foscht & Swoboda, 2011, P. 103, Kroeber-Riel & Gröppel-Klein, 2013, p.372).

Now that information has been recorded, processed and evaluated, the process of (3) information storage follows in a third step. When storing information, the two processes of knowledge and learning are particularly significant. Stored product knowledge is in a sense the precondition for the fact that new product information can easily be taken up by the consumer and learned easily (see Kroeber-Riel & Gröppel-Klein, 2013, p. 432). The learning process itself involves the permanent storage of information in long-term memory (Kroeber-Riel & Gröppel-Klein, 2013, p. 430). According to Squire (2004, p. 173), memory is structured into a declarative and a non-declarative memory. The contents of the declarative memory are facts and events, for example, product knowledge and consumer experiences. By contrast, non-declarative memory is unconscious.

The marketing practice is primarily interested in triggering the advertising messages in the memory of the consumers. For example, ads or ad elements. In general, the use of images in advertisements has a positive effect on attitudes toward ad elements and ultimately on advertising recall (see Pieters & Wedel, 2004, p.) On the other hand, the quality of an advertising medium is measured by the extent to which it has a high recognition value. Basically, ads have a high recognition value, if the information conveyed by image and text can be easily decrypted by the consumer. Thus, the decryption of stimuli in the context of information processing already forms the basis for the recognition of an advertisement. It follows that information processing and storage can not be considered separately, but are interdependent (see Venkatraman et al., In press, p. 43).

In this section I explained in detail which activating processes (emotion, motivation, attitude) drive the consumer. Second, I outlined how and to what extent consumers receive, process and store information. The following section 2.1.4. gives a brief overview of the neuroanatomical foundations of mental processes to allow a rough orientation in the brain.

### 2.1.4. Neuroanatomical Foundations of Psychic Processes

As also mentioned in the introduction, the psychic process of the consumer has recently been intensively analyzed thanks to the inclusion of insights from the neurosciences (see Kroeber-Riel & Gröppel-Klein, 2013, p.43). The following text attempts to assign neuroanatomical origins to the psychic process of the consumer. It deals with specific brain structures which relates to consumer behavior. So a basic understanding should be created for the neuroanatomical bases of activating and cognitive processes.

Before describing the consumption relevant functions of the brain structures, a brief characterization of the three most important brain parts of the brain will be shown (see Gerrig & Zimbardo, 2008, p.90). The innermost layer of the human brain forms the brain stem. The brain stem is adjoined by the limbic system, which consists of three structures. The hippocampus, the amygdala and the hypothalamus. The brainstem and limbic system are surrounded by a third layer, the cerebrum.

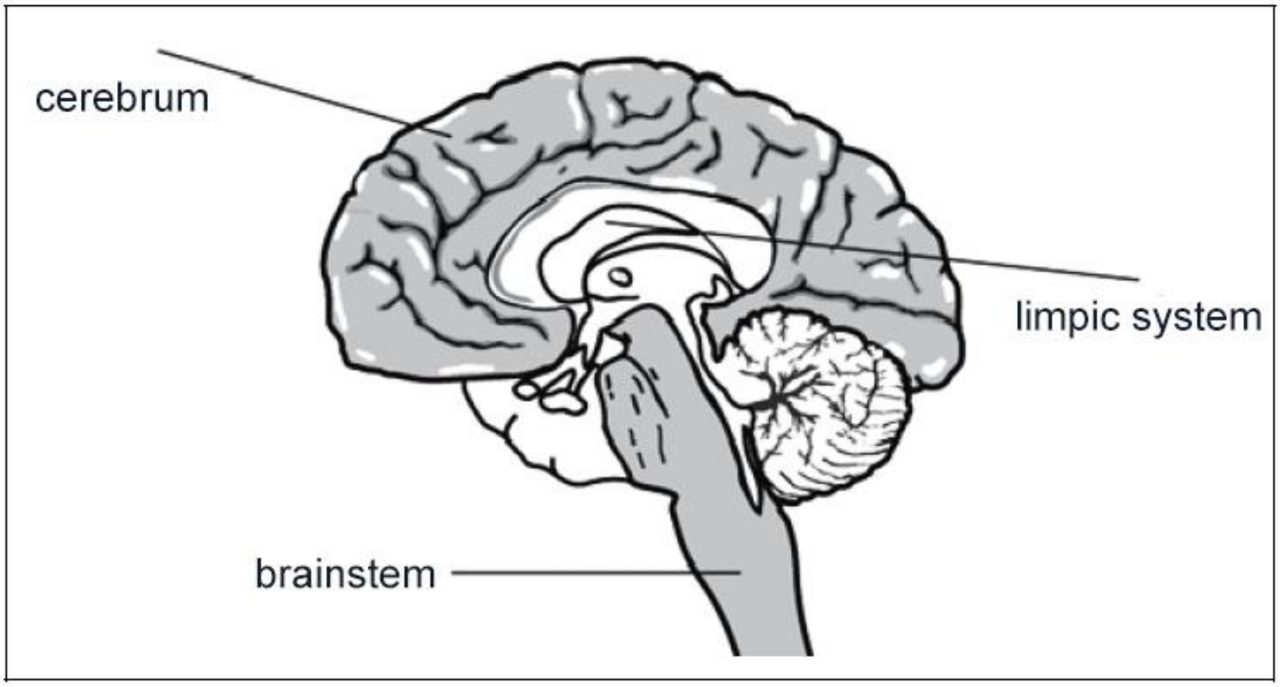


**Figure 4:** The human brain (based on Gerrig & Zimbardo, 2008, p. 91)

The inner part of the brain stem, the so-called Formatio reticularis is responsible for the general activation of the organism. In addition, the reticular formation is responsible for the control of alertness or attention (see Sokolowski, 2008, p.83). Furthermore, the ascending reticular activation system controls eye and head movements that occur in response to new stimuli (see Gerrig & Zimbardo, 2008, p.90). The complex activating processes arise through the interaction of functions of different brain structures.

A decisive role in the explanation of emotions plays the limbic system, as MacLean (1952, p. 407) discovered in the middle of the last century: "the limbic system represents an early expression of emotional development and expression".

As mentioned earlier, the limbic system consists of the three structures amygdala, hypothalamus and hippocampus. In terms of consumer behavior, the amygdala is very interesting. This part of the brain is primarily responsible for communicating negative emotions and for the emotional conditioning of anxiety (see Dalgleish, Dunn & Mobbs, 2009, p 359). Closely connected with the amygdala and the hippocampus is the hypothalamus. The hypothalamus is responible for controlling of emotions and in the regulation of physiological process of motivational behavior. Furthermore, the hypothalamus is responsible for attention control (see Birbaumer & Schmidt, 2010, pp. 75, 78, Gerrig & Zimbardo, 2008, p.145).

On the other hand, the hippocampus plays also a big role in the brain process. Kroeber-Riel and Gröppel-Klein (2013, p. 419) describe the hippocampus as a "gateway to memory". Specifically, it is responsible for acquiring explicit memory content and organizing declarative memory (see Shohamy & Turk-Browne, 2013, p. 160). It should also be pointed out that the hippocampus is not responsible for the storage of knowledge, but only for the organization of knowledge (see Roth, 2004, p. 498, Shohamy & Turk-Browne, 2013, p.43). The cerebrum and cerebral cortex are generally responsible for memory. The cerebral cortex, also called the cerebral cortex, is the outer surface of the cerebrum. The cerebrum itself consists of two halves. The two halves are each specialized in different functions, with no clear division of responsibilities between the two halves. Basically, the assumption is that the memory for words, speech and numbers is a left-hemispheric function. In turn, it is assumed that the memory for outlines and music is a right-hemispheric function (see Foscht & Swoboda, 2011, p. 87). However, recent studies question this function classification (see Bizzi et al., 2012, p. 255).

The brain structures presented in this section and their associated functions were identified using neuroscientific measurement techniques. The following section provides an overview of the most important neuroscientific procedures and the research field of Consumer behaviour.

### 2.2. Theoretical Foundations of Consumer Neuroscience

With the "classical" methods of consumer behavior research, for example, with the questioning and observation, the psychic process inside the consumer can only be detected indirectly. Thanks to technological advances in the field of medicine and radiology, methods of brain research now enable direct measurement of thoughts and feelings (Camerer, Loewenstein & Prelec, 2005, p. 10). Consumer Neuroscience takes advantage of this potential of neuroscientific measurement methods, as shown in Figure 5. The following figure also illustrates that the second section of the second chapter provides an overview of the emerging field of research in consumer neuroscience (see Section 2.2.1.). Based on this, the neuroscientific procedures that are suitable for the research projects of consumer neuroscience are presented and evaluated (see Section 2.2.2.).

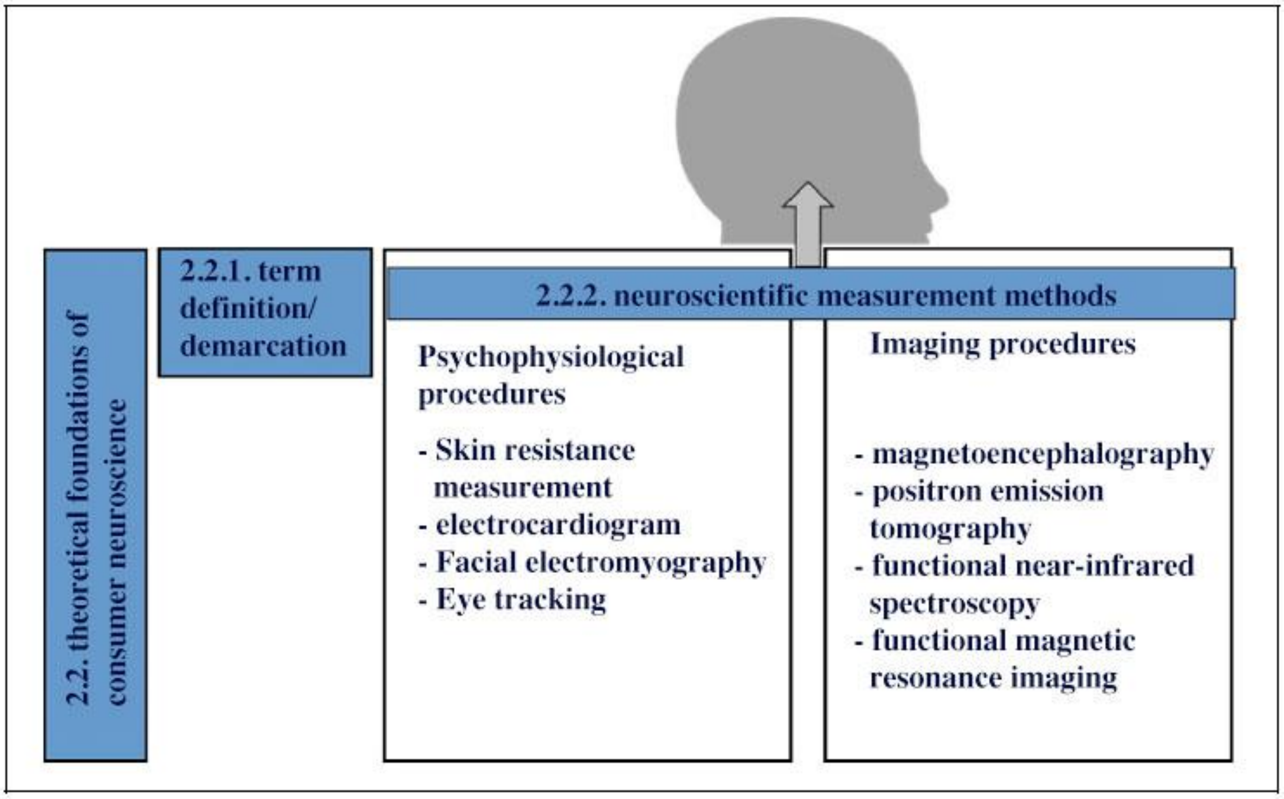


**Figure 5:** Structure of section 2.2.

#### 2.2.1. Definition of terms and demarcation

The term Consumer Neuroscience describes the application of insights and methods in neuroscience with the aim of analyzing and understanding marketing-relevant problems and consumer behavior (see Lee, Broderick & Chamberlain, 2007, p 200, Smidts et al., 2014, p 258). This definition makes it clear that the discipline of consumer neuroscience covers a wide range of topics. On the one hand, the research interest focuses on the four elements of the marketing mix, which is why consumer neuroscience is characterized by a high level of practical relevance (see Smidts et al., 2014, P. 258). For example, research results can help companies to understand better the needs of consumers or also develop improved product solutions (see Ariely & Berns, 2010, p.94). On the other hand, the Consumer Neuroscience tries to explain the behavior of consumers. The results may be useful in consumer policy (see Kenning & Linzmajer, 2011, p. 112, 121).

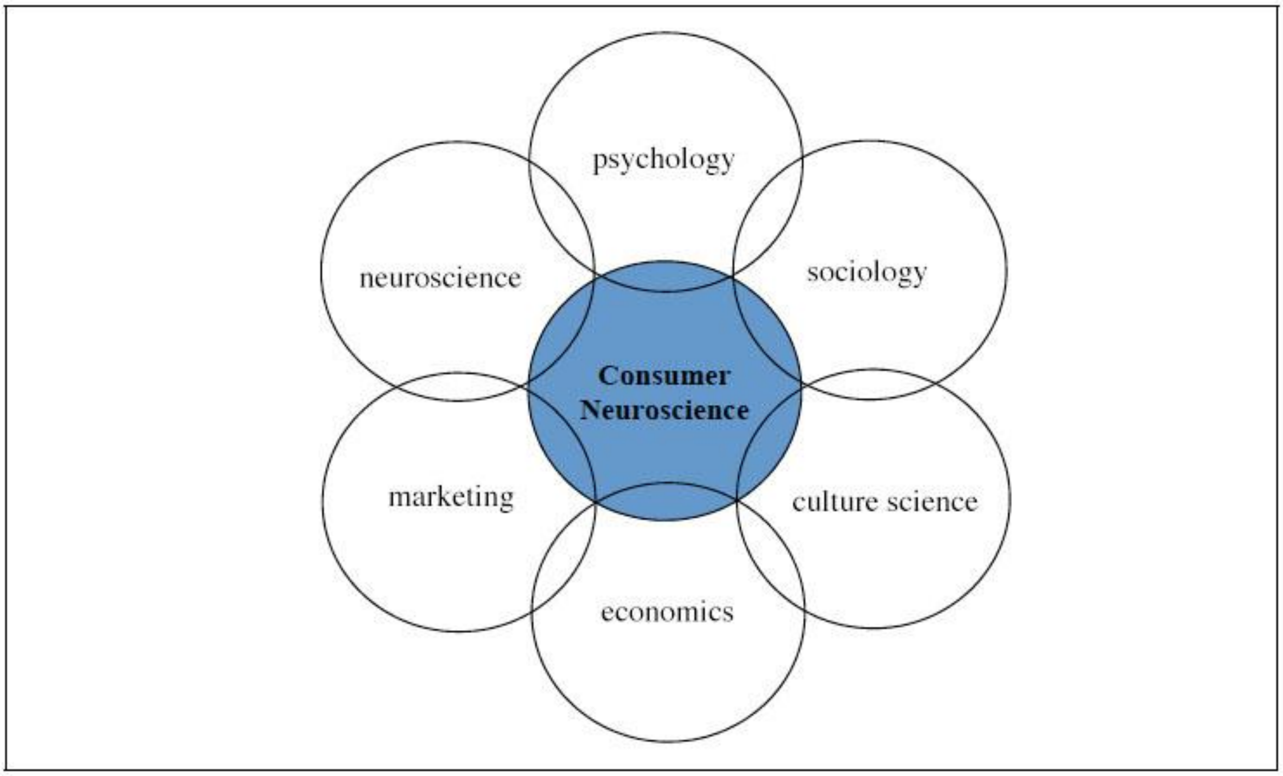


**Figure 6:** This shows that Consumer Neuroscience integrates and combines a wide range of findings from neuroscience, psychology, sociology, cultural studies, economics and marketing to explain marketing-relevant consumer behaviour.

In the same context as the term Consumer Neuroscience, the term neuromarketing is used in practical literature, and more rarely in scientific publications (see Felser, 2013; Hugel, 2014). Even if neither of the two terms has clearly prevailed over the other, the term "consumer neuroscience" is used in this work because it has a stronger connection to consumer behavior research.

Consumer Neuroscience is a sub-discipline of neuromarketing and neuroeconomics. This field of research developed in the late 1990s when, according to Glimcher and Rustichini (2004, p. 452), " economics, Marketing, psychology, and neuroscience merged into a single, unified field". The merger of these disciplines into interdisciplinary neuroeconomics is based on the fact that both the social sciences and the neurosciences share a common interest in understanding the mechanisms of human behavior (see Levallois, Clithero, Wouters, Smidts & Huettel, 2012, p. 789). Specifically, the goal of neuroeconomics is to relate theories of decision-making behavior of the human brain. In this way an attempt is made to develop economic models based on a more realistic description of human behavior (Camerer, 2008, p.416; Kenning & Plassmann, 2005, p. 343).

Meanwhile, the number of neuroscience studies in consumer and marketing research is steadily growing. There are lots of conferences, summer schools and symposia focusing on consumer neuroscience (see Smidts et al., 2014, p.42). But this development has only recently been observed. Neuroscientific research methods are slowly finding their way into the faculties of economics. This circumstance can be attributed to the fact that the topic of neuroscience is intimidating and that there are barriers at universities which make interdisciplinary cooperation between business and neuroscientists more difficult (see Lee et al., 2007, p.87). In addition, some brain researchers have moral concerns about using neuroscientific methods to find the "buy button in the brain" (Brain scam ?, 2004, p. 683). Levallois establish the barriers between the disciplines. Despite the adversities described, significant advances in knowledge and methods were achieved in the research environment of consumer neuroscience, which, for example, led to an improved understanding of the brain activities of consumers (see Smidts et al., 2014, p.32). The following section provides an overview of the neuroscientific methods used to study consumer behavior.

### 2.2.2. Neuroscientific measurement methods

There are numerous methods used in Consumer Neuroscience. These methods are classified in two classes of psychophysiological and imaging techniques (see Dimoka et al., 2012, p 680, Kenning, Plassmann & Ahlert, 2007, p 57). These mentioned methods will be discussed and characterized in more detail. It starts with the psychophysiological procedures, followed by the imaging techniques. Imaging techniques are the focus of this section as they have become more and more important to neuroscience over the past twenty years. This is confirmed by the authors of the scientific journal Neuroimage „Neuroimaging has been and still is one of the most important tools available to study the brain"(Toga, Frackowiak & Mazziotta, 2012, S. 323).

**Psychophysiological procedures**

The psychophysiological methods measure skin resistance, electrocardiogram, facial electromyography and eye tracking (Camerer et al., 2005, p 14; Dimoka et al., 2012, p. 681).

The method of skin resistance measurement was very popular, especially in the 1960s and 1970s (see Kroeber-Riel, 1979, p 243). In this method, electrodes are attached to the middle and index fingers to measure changes in skin electrical conductivity when exposed to stimuli (see Boshoff, 2012, p.23). The more sweat secreted in the palms, the higher the conductivity of the skin. Thus, the level of sweat level provides information about which activation potential a stimulus possesses (see Boshoff, 2012, p.4, Camerer et al., 2005, p. 67). In a study by Boshoff (2012), skin resistance measurement was used to investigate consumer emotional reactions to service recovery measures.

With the help of electrocardiogram, the heart rate or pulse rate can be measured. For this purpose, electrodes are attached to the body of the subjects during the measurement, which record the electrical impulses of the heart (see Kenning, 2014, p.95). The heart rate is controlled by the interaction of sympathetic and parasympathetic nervous system. Once the sympathetic nervous system is activated by a stimulus, the heartbeat and blood pressure of the person increases. This effect can be used, for example, in advertising impact research to measure the arousal of a consumer. In contrast, the parasympathetic nervous system ensures relaxation in the body. It is thus a good indicator of the attention that a consumer encounters when viewing an advertisement.

Facial electromyography measures the facial expressions of a subject or the activity of individual facial muscles (see Kenning, 2014, p.67). As part of the measurement, electrodes are attached to the left side of the face of the subjects (see Likowski et al., 2012, p.157). Facial electromyography is based on the assumption that movements of the facial muscles are associated with emotional reactions (see Wolf et al., 2005, p. 403). Walla, Brenner and Koller (2011) used facial electromyography in a study to measure positive and negative attitudes towards brand names. Finally, the eye tracking method will be briefly explained. Eye movements include fixation on the one hand, and saccades[6] on

[6] Fixations are 200-300 ms lasting periods during which the gaze stops and the eye absorbs environmental stimuli. Saccades are eye movements that take place between fixations in order to refocus the gaze (see Rayner, 1998, pp. 372-

the other hand. In addition, some eye tracking studies aim to measure the diameter of the pupil, as dilated pupils are an indication of increased attention (see Pieters & Wedel, 2007, p. 225). Recent developments in computer technology mean that screens can record the eye movement of subjects with the aid of infrared sensors (see Kenning, 2014, p. 142). Such a technique was also used by Pieters, Wedel and Batra (2010) in their study. The authors use the eye tracking method to show that design complexity in ads has a positive effect on Attitude Toward the Ad (Pieters et al., 2010, p. 58).

In summary, it can be stated that the psychophysiological procedures are relatively simple to use, provide fast results and do not cause high measurement costs (Cramer et al., 2005, p.43). On the other hand, the psychophysiological procedures have also disadvantages. Psychophysiological methods do not allow direct measurement of neuronal activity. Instead, based on physical reactions (e.g.heart rate) measurements can be assumed.

**Imaging procedures**

The most important imaging techniques for consumer neuroscience are differentiated into electrophysiological and metabolic procedures. While electrophysiological methods measure direct brain activity, metabolic processes detect blood flow and assume that mental activity results in increased metabolic turnover in the brain region (see Shiv et al., 2005, p. 380).

The most common electrophysiological procedures include electroencephalography (EEG) and magnetoencephalography (MEG). The EEG is one of the oldest neuroscientific methods, which detects electrical brain waves. In EEG electrodes are attached to the head of the test persons in order to measure voltage fluctuations on the skull surface (Michel & Murray, 2012, p.372). Thanks to the high temporal resolution of the EEG, it is possible to measure in high detail (see Ariely & Berns, 2010, p 288, Kable, 2011, p.91). Another advantage of the EEG method is that it is relatively inexpensive compared to other neuroscientific methods (see Ariely & Berns, 2010, p. 288). In EEG studies a high degree of realism of the experimental situation can be achieved, since the EEG is quiet, permits movements of the test persons and is also transportable, so that experiments do not necessarily have to take place in the laboratory. A major disadvantage of the EEG is its low spatial resolution. According to Ariely and Berns, researchers have the ability to influence the quality of spatial

373).

resolution: "The greater the number of electrodes, the better the spatial resolution". Apart from that, only activities in the outermost layers of the brain can be measured by EEG. With this method the localization of nerve cell activities in deeper brain layers is not possible (Salmelin & Baillet, 2009, p.155, Shiv et al. , 2005, p. 381).

Closely related to the EEG is the MEG. Researchers measure with the MEG method weak, magnetic fields that are caused by brain waves (see Ariely & Berns, 2010, p 288, Kable, 2011, p 70). MEG uses highly sensitive sensors called superconducting quantum interference devices (SQUIDs) to measure magnetic fields (see Kenning, 2014, p.143). It is positive that the MEG can detect activities in deeper brain layers (see Kenning, 2014, p53). Compared to the metabolic methods, the spatial resolution of the MEG is very low (see Blow, 2008). Although Ariely and Berns (2010, p. 288) postulate that the MEG has a better spatial resolution, because the magnetic fields of the brain waves are less distorted by the skull than the electric fields). Moreover, this technique is associated with relatively high measurement costs and complex statistical data analysis (Lee & Chamberlain, 2007, p.46) In addition, the electrical activities of nerve cells can not be monitored in real time using the MEG method (see Salmelin & Baillet, 2009, p. 154).

The next technique I want to show is positron emission tomography (PET) and functional near infrared spectroscopy (fNIRS) will be briefly discussed in connection with the most important metabolic processes. For me the most important method is the Functional magnetic resonance imaging (fMRI) to use for Marketing research, which how you separetely in the third chapter.

PET, one of the older neuroscientific methods, is based on nuclear medicine technology. It measures metabolic processes in the nerve cells, which occur as follows (see Kenning et al., 2007, p.57). In cognitive activity there is an increased energy and oxygen consumption in the affected brain regions. The brain demands in this case more and more for glucose and oxygen. The PET measures the glucose and oxygen concentration in the brain and thus indirectly maps the activation distribution in the brain areas. The prerequisite for carrying out a PET measurement is that glucose and oxygen are radioactively labeled. Radioactive labeling is necessary because the molecules glucose and oxygen do not emit electromagnetic signals. The application of the PET method suggests that it has a better spatial resolution than, for example, the EEG and MEG (Camerer et al., 2005, p.). It should also be mensioned positively that no appreciable noise development occurs during a PET measurement, and thus a high degree of realism of the experimental situation can be achieved (see Stern et al., 2005, p.).

Third, the PET is certified high sensitivity. The very poor temporal resolution can be cited as disadvantageous (cf Camerer et al., 2005, p51). A recent PET study related to consumer neuroscience was conducted by Lepage (2004). A non-invasive method is the fNIRS, whose functioning depends on the properties (see Kable, 2011, p. 70; Kenning, 2014, p. 139).

The fNIRS makes use of the fact that neural activities increase blood flow of the brain. Specifically, the fNIRS measures the concentration changes of oxygenated (oxygen-rich) and deoxygenated (oxygen-poor), because when activating a brain area, the concentration of oxygenated increases Hemoglobin, while in turn the concentration of deoxygenated hemoglobin is reduced (see Kenning, 2014, p.86). One of the advantages of fNIRS is that it is characterized by a good temporal resolution. So it is possible for example, to depict rapid changes in the oxy- and deoxyhemoglobin concentration (Kable, 2011, p. 71). The fNIRS method is relatively inexpensive but a weakness of fNIRS is that their temporal resolving power is worse than that of the EEG and MEG (see Kenning, 2014, p.66). Current FNRIS studies investigate, for example, the effect of visual and acoustic stimuli on the Decision-making behavior (see Köchel et al., 2011; Plichta et al., 2011)

| | Method | strengths and weaknesses | Source |
|---|---|---|---|
| Electrophysiological procedure | EEG | + high temporal resolution<br>+ low measuring costs<br>+ realistic experimental conditions<br>+ non-invasive<br>- low spatial resolution<br>- no localization of activities in deeper brain layers<br>- unwieldiness | Ariely & Berns, 2010, S. 288; Camerer et al., 2005, S. 12; Kable, 2011, S. 69-70; Michel & Murray, 2012, S. 372; Salmelin & Baillet, 2009, S. 1754-1755; Shiv et al., 2005, S. 381-382 |
| | MEG | + high temporal resolution<br>+ localization of activities in deeper brain layers<br>+ non-invasive<br>- low spatial resolution<br>- low sensitivity<br>- high measurement costs<br>- complex statistical data analysis<br>- artificial experimental conditions | Ahlfors et al., 2010, S. 230; Ariely & Berns, 2010, S. 288; Blow, 2008, S. 984-985; Kable, 2011, S. 70; Malmivuo, 2012, S. 17; Salmelin & Baillet, 2009, S. 1754; Shiv et al., 2005, S. 380-381; Singh, 2012, S. 1123 |
| | PET | high spatial resolution<br>+ realistic experimental conditions<br>+ high sensitivity<br>- Low temporal resolution<br>- Invasive<br>- Radiation exposure of the probanden | Camerer et al., 2005, S. 12; Kenning et al., 2007, S. 57; Stern et al., 2005, S. 36-38; Zimmer & Luxen, 2012, S. 364 |
| Metabolic processes | fNIRS | + high temporal resolution<br>+ natural examination situation<br>+ low measuring costs<br>+ no noise development- less good time resolution<br>- low reliability of the results of the measurements<br>- complxe statistical data analysis | Boas et al., 2014, S. 1; Kable, 2011, S. 70-71; Kenning, 2014, S. 88, 139-140; Kopton & Kenning, 2014, S. 9; Riedl et al., 2010b, S. 247; Scholkmann et al., 2014, S. 7, 14 |
| | fMRT | page 3 | |

**Table 2:** Summarizes the strengths and weaknesses of the illustrated imaging techniques once together.

# 3. Overview of the procedure

The first fMRI experiment in the US state of Massachusetts was 25 years ago.

At first this method was only used in the medical neuroscience but soon the fMRT method found its way into economic and in the business area.

The fMRI is based on the method of classical magnetic resonance tomography (MRI). The measuring principle of MRI consists of the deflection and relaxation from magnetically caused protons in the human organism(see Birbaumer & Schmidt, 2010, p 486). For this purpose participants are placed in a tube. Participants then are surrounded by a strong magnetic field that generates pulses. In the first step, the Field pulses order protons residing in human tissue in a parallel structure. In a second step strong RF pulses hit the Protons, which leads to a further deflection. After that, the protons return to their Starting position points (relaxation). During relaxation, the protons produce electromagnetic waves that are picked up by detectors. This process is the so-called magnetic resonance signal. Different body tissues generate different magnetic resonance signals.

For this reason, it is possible to use different tissue structures, such as the brain, (see Birbaumer & Schmidt, 2010, p. 488). An advancement of the MRT is the fMRI. While the goal of MRT is to identify tissue structures the fMRI tries to map neuronal brain activities (see Weiskopf, 2012, pp. 682-683).

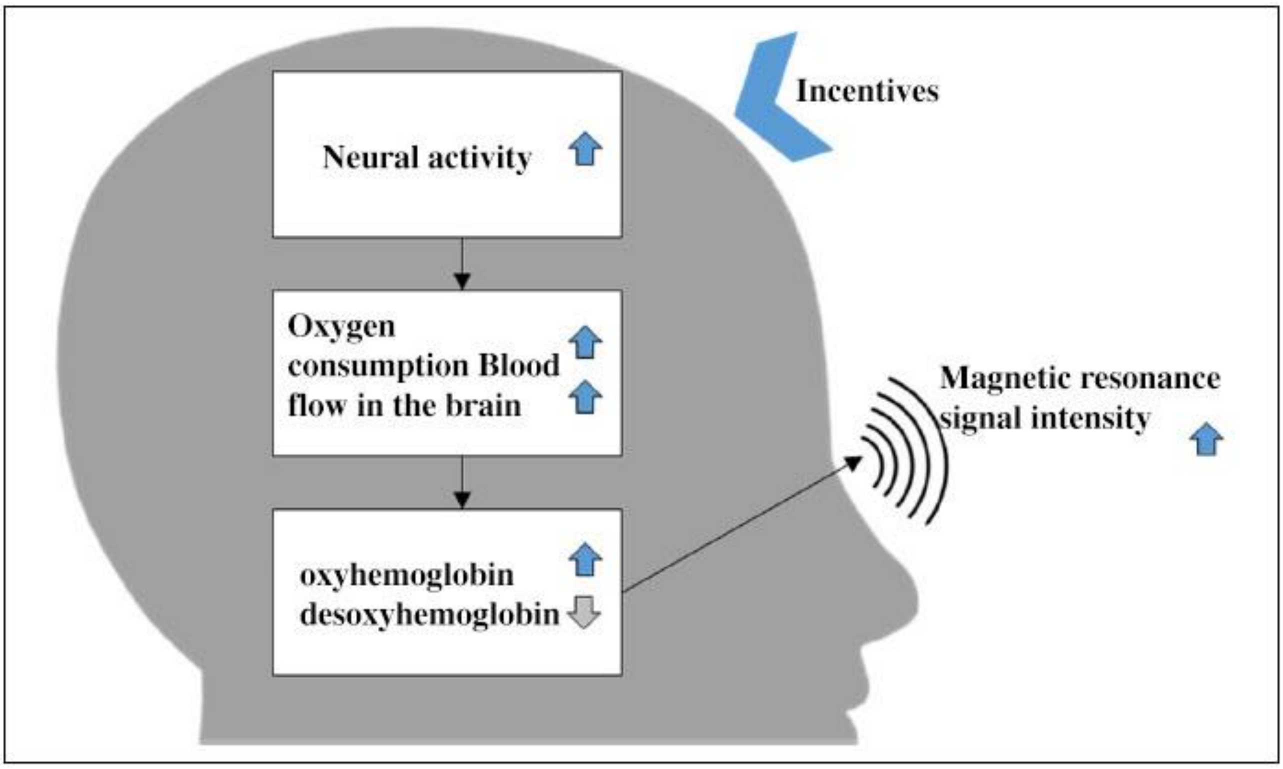

**Figure 7:** Schematic representation of the BOLD effect (based on Miyapuram, 2009, p. 37)

The last part of this section deals with functional imaging. As described in the beginning, the magnetic resonance signals are in the context of an fMRI measurement received by detectors of the brain scanner. After that a mathematical-statistical software transfers the magnetic resonance signals in an image together (see Kenning, 2014, p. 39). In this process, the brain is not the recorded as a whole piece but recorded in layers. Usually, 30 or more brain layers are recorded during this process. (see Huettel, Song & McCarthy, 2014, p. 274).

The fMRI method is now considered as "gold standard" (Cui, Bray, Bryant, Glover & Reiss, 2011, p. 808) for the study of the human brain. The strength and weaknesses of the fMRI are highlighted in the following section

### 3.1. Strengths and weaknesses of the procedure

The advantage is that the fMRI is a non-invasive procedure, unlike the PET causes no radiation exposure (see Bandettini, 2012, p. 76). The Participation in fMRI studies for volunteers is totally harmless (see Kenning, 2014, p. 39). Second, Huettel (2012, p. 153) points out that the core advantage of fMRI does not come from the flexibility of its experiments ".„the core advantage of fMRI does not come from the nature of its data […] but from the flexibility of its experiments”. On the other hand, the fMRI method allows a complex data analyses (see Huettel, 2012, p. 53; Savoy, 2012, p. 204). Third, the fMRI is characterized by a high spatial Dissolution (see Bandettini, 2012, p. 76). This has the advantage that activity of specific brain regions can be accurately located. Depending on the Scanner technology it is possible to have structural images of the human brain with a very good resolution. In contrast to the spatial resolution, the temporal resolution of the fMRI is comparatively mediocre (see Kable, 2011, p. 234). On average, the temporal delay in fMRI recordings is about two to three seconds (see De Houwer, 2011, p. 312). For comparison: The EEG and the MEG capture mental processes within milliseconds (see Kable, 2011, p.78). Nonetheless, the fMRI is among all the neuroscientific methods the one that has the best combination of spatial and temporal resolution (see Kable, 2011, p.79). In addition, the scanner technology is improving from year to year, so that brain activity can be displayed almost in real time (see Dimoka, 2012, p. 84). Further should be taken into account that fMRI studies are high on costs. According to Dimoka (2012, p. 681), the cost of a scan per hour is about between $ 200 and $ 500. This requires special software program skills for data analysis, such as Statistical Parametric Mapping (SPM) or BrainVoyager.

## 3.2. Process of empirical investigations by means of the fMRI

First of all, the procedural sequence of fMRI examinations will be traced (Section 3.2.1.). This is followed by a brief characterization of the individual process steps (see section 3.2.2.). Specifically, for each individual process step the empirical investigation shows which design possibilities are conceivable.

### 3.2.1. Process scheme for empirical investigations by means of the fMRI

The conception and execution of an empirical investigation by means of the fMRI can be represented as a process. There seems to be a breakdown of the investigation in five process steps (Kellermann & Habel, 2013, p. 133; Kenning, 2014, p. 93). The first step consists of the formulation of the neuroeconomic question (see Huettel et al., 2014, p. 326). Here, a problem field from the consumer behavior research must be identified so that the fMRT can be used. Kenning (2014, p. 92) notes that the fMRT is suitable for almost all psychophysiological questions in the field of consumer behaviour. basically, fMRI studies are designed as an experiment (see Kable, 2011, p. 69).

Therefore, in the second step, decisions have to be made regarding the structure and the experimental design of the fMRI study. Every experiment is characterized by a cause-and-effect relationship between various variables. Within an experiment, there are two Types of variables: independent and dependent variables. One or more independent Variables are manipulated in the context of the experiment to determine their influence to be able to check them for the respective dependent variables. Goal of an experiment is to determine if a particular independent variable influences a particular dependent variable (see Kuß, 2013, pp. 165-166). The described cause-effect relationship is described below using a recent fMRI study.

Third, for a successful fMRI study it is acquired to have suitable probands. When acquiring probands certain criteria must be taken into account. For example, Epileptics, people with heart problems, or people with metals in the body, pregnant women and Claustrophobics are strictly excluded from participation in fMRI studies (see Pauly & Habel, 2013, pp. 120-122). The period is called a session, in which a Proband is in the magnetic resonance scanner. Each session lasts about one to two hours. In the process, the first minutes of the session become a structural measurement. This means that only the anatomy of the participant's brain is scanned. Afterwards the functional measurement takes place. The functional measurement includes several so called runs. During these runs a proband become the subject Stimuli presented and received appropriate responses of the brain. (see. Huettel et al., 2014, pp. 274-275).

In the fourth step, a data analysis is performed. A fundamental component data analysis is the preparation of fMRI data. As in section 3.1.1. described, the BOLD signal is collected in layers as part of the data collection process. Finally, the fifth step is followed by the interpretation of the evaluated fMRI data. As a matter of principle, the question arises the meaning of brain activities and it is imaged by the fMRI (see Kenning, 2014, p. 112).

### 3.2.2. Process steps of empirical investigations by means of the fMRI

As in section 3.2.1. showed an empirical investigation using the fMRI can be subdivided into five process steps. This section shows which aspects within of each process step are design-relevant. The first process step for the formulation of the neuroeconomic problem comprises three essential aspects. The research objective is defined, research questions are formulated and hypotheses are set up (see Dimoka, 2012, pp. 813-817; Kenning, 2014, pp. 92-93).

The second process step is to transform the formulated hypotheses into an experimental one. An important consideration in this context is the choice of stimulus material. In addition, the question arises the number of independent variables and how the independent variables are manipulated. The most important aspect is the choice of the experimental paradigm.

The third process step concerns the selection of the Probands. Relevant design Criteria of the proband selection are age as well as sex. A central point is in addition, the determination of the sample size (see Barton, Berns & Brooks, 2014, p. 74). There are no design options with regard to data collection. Worth mentioning is in connection with the fMRI measurement, which takes place under relatively artificial conditions (see Riedl et al., 2010b, p. 255).

The fourth process step, data analysis, opens up two basic options: on the one hand the functional specialization and on the other the functional integration. Statistical data analysis of functional specialization is suitable to localize activated brain regions. In contrast, statistical Data analysis of functional integration performed with the objective to Identify relationships between different brain regions (see Friston, 1994, p. 58; Hubert, Linzmajer, Riedl, Kenning & Hubert, 2012, Pp. 1-4).

The fifth process step ultimately involves the interpretation of the study results. Here are two approaches: the forward inference and the reverse Inference (see Henson, 2006, p.64; Poldrack, 2006, p. 59).

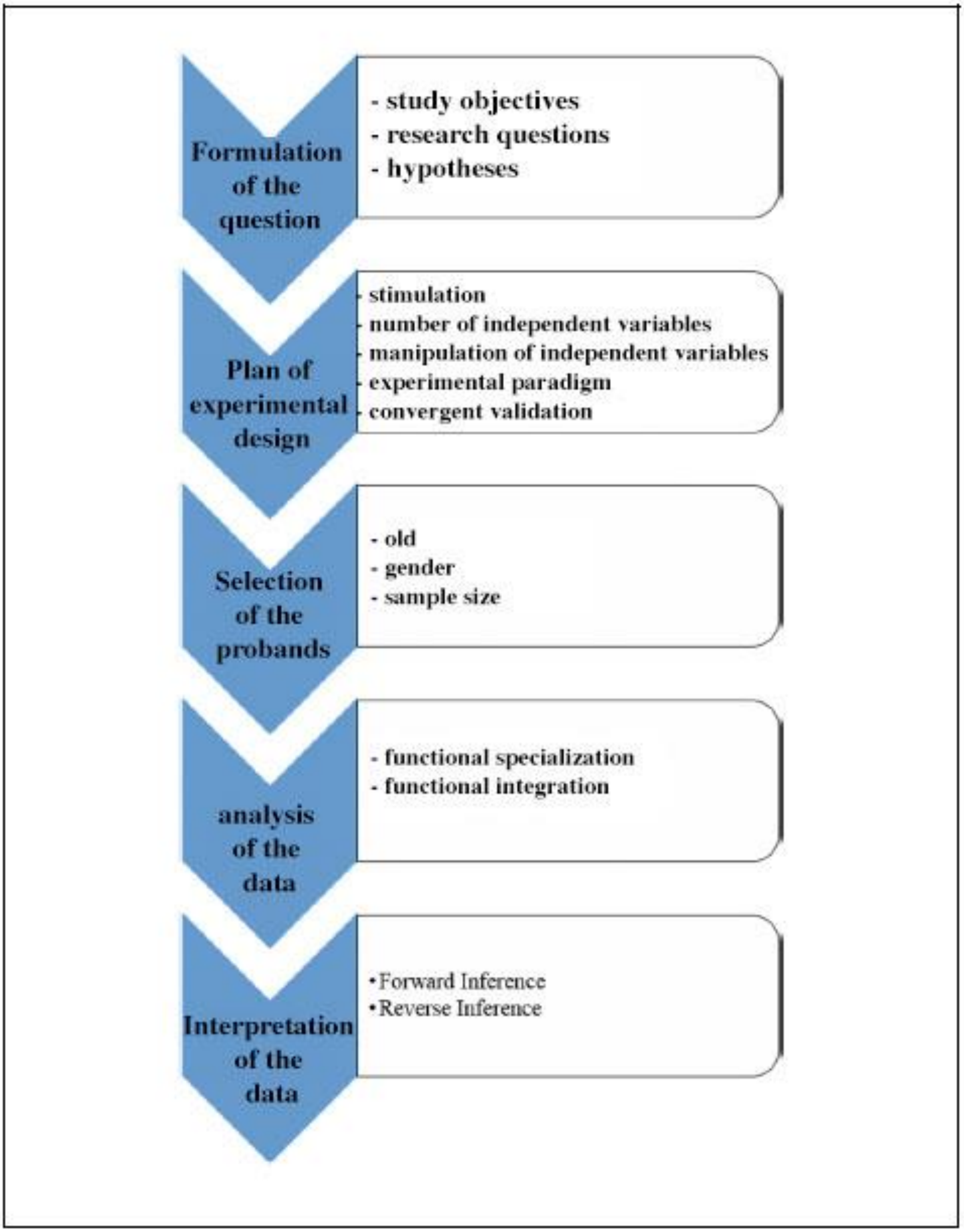


**Figure 8:** Shows the individual process steps of an empirical investigation represented by the fMRI. These design options of empirical fMRI investigations are described in detail in Chapter 4 below.

# 4. Design options of empirical investigations by means of the fMRI

The structure of the fourth chapter is based on the process scheme of an empirical Investigation, which was explained in the previous section 3.2.1. The reason for that is that design options of empirical studies is better when using the fMRI if the design-relevant aspects correspond to the respective process steps.

The methods and study designs showed in this chapter are intended to identify options for action and methodical orientation with regard to the design and implementation of an fMRI study. To this end an extensive literature search was carried out. A major criterion of the literature search was to ensure the quality of the literature[7]. The focus was placed on prestigious journals, which are marked as good ranking journals. Additional consideration was given firstly for publications from Marketing.

Secondly, additional neuroscience journals were considered as well during my research. The second criterion of the literature search refers to the type of sighted Posts. As derived from the initially described objective of this chapter I was interested in theoretical work with methodical priorities. The third criterion is that the literature I have chosen fits exactly with my thesis. In principle the focus is on reviews that deal with methodological aspects of fMRI studies and why they are so important for marketing purposes. In addition, fMRI studies have a strong relation to questions of consumer behaviour.

Even such studies were considered that are not part of the research field of Consumer Neuroscience, but relevant mental processes (see Section 2.1.3.). The fourth criterion refers to the time of publication. Profound methodological developments are probably possible rather to read from empirical work. For this reason, only fMRI studies, which were published in scientific journal after 1 January 2010.

[7] The Association of University Professors for Business Administration e.V. (VHB) publishes the VHB-JOURQUAL at regular intervals(see Henning-Thurau, Walsh & Schrader, 2004)

### 4.1. Formulation of the neuroeconomic question

In this section I discuss the numerous options in the definition of the neuroeconomic Question. Different research objectives are considered (see section 4.1.1.) as well as types of research questions (see section 4.1.2.) and hypotheses (see section 4.1.3.). The section concludes with an overview about all discussed design options.

#### 4.1.1. aims of analysis

FMRI studies in the field of consumer neuroscience can be very different. Basically, four different aim of analysis can be differentiated from fMRI studies: Generation of more meaningful Dates, Scale validation, Prediction of consumer behavior and Review of Theories (Huettel & Payne, 2009, p. 16; Kenning, 2014, pp. 92-94). This section highlights the different Options in the definition of the aims of analysis and concretizes these on the basis of example studies.

**Generation of meaningful data**

According to Dimoka (2012, p. 813), the use of the fMRI is justified if other simplier and cheaper methods do not provide better meaningful insights as the fMRI study. This applies in particular to the measurement of mental processes inside the consumer (see the comments on the S-O-R model in Section 2.1.2.). On the one hand, mental processes such as emotion, motivation, Attitude and information cannot be put in words since they are unconscious (see Plassmann et al., 2010, p. 8; Plassmann et al., in press, pp. 6-7). On the other hand, there are sensitive research topics that are hidden Emotions or moral issues that subjects are reluctant to talk about (see Aue, Lavelle & Cacioppo, 2009, p.78). The fMRI offers the possibility to bypass oral statements of subjects and to grasp psychic processes directly. In addition, when performing a fMRI study measuring errors caused by socially desirable responses can be avoided (see Dimoka, 2012, pp. 163-164). Finally, Scientists take advantage of the real-time procedures in the fMRI (See Dimoka, 2012, p 814, Mathiak, Goebel & Weiskopf, 2013, p.104). As soon as a test subject encounters a stimulus during fMRI measurement, resulting brain activities are made immediately visible (see Sulzer et al., 2013, P. 387). The real-time method is especially suited to higher-ranking cognitive and emotional processes. In addition, the real-time fMRI provides intuitive access to the collected data. For example, scientist can make temporal or even causal connections between constructs, processes and behaviors (see Dimoka, 2012, P. 814).

An antagonistic decision is made by Craig, Loureiro, Wood and Vendemia (2012), who examine in their study which neural structures are activated when Consumers are exposed to fraudulent advertising. Cognitive theories assume that Consumers acquire knowledge over time about the Intentions behind marketing activities such as advertisements. The appropriation of this knowledge can be described as a complex psychic process, which roughly refers to the fact that consumers are able to differentiate wishes from the desires and intentions from others (cf. Craig et al., 2012, p. 363).

The study by Hedgcock, Vohs and Rao (2012) on the study of self-control Consumers also use the ability of real-time fMRI, to map neuronal activity over time. As part of the investigation, probands had the task of ignoring words that appeared on a screen (cf. Hedgcock et al., 2012, p. 88). The study participants should therefore deliberately suppress their impuleses to look. The evaluation of the fMRI data shows that with every further conscious suppression the activity in the Brain area of impulse control is somewhat lower (see Hedgcock et al., 2012, p. 490). Thus, the authors prove that self-regulation are limited and loses his effect over time.

**Validation of scaling methods**

Another possible research objective is the validation of scaling methods, which are used in consumer behavior research and marketing (see Plassmann et al., 2010, p.83). For example, Schaefer and Rotte (2010, p. 274) set themselves the goal in their study an established scaling method to validate the so-called semantic differential. The judgments that are collected using the semantic differential[8] can usually be reduced to three basic factors by a factor analysis (see Osgood, Suci & Tannenbaum, 1957, p.53). Today, there is research Disagreement over how to correctly design the basic factors (see Schaefer & Rotte, 2010, p. 275).

[8] The semantic differential, also called polarity profile, measures multi-dimensional constructs (e.g., the brand image). The Proband is presented with a number of opposing adjectives (inter alia strong vs. weak). The subject is then asked to mark the extent to which the respective adjective reflects its associations to the construct.

**Prediction of consumer behaviour**

In addition, Berkman and Falk (2013, p. 45) argue that the fMRI method meanwhile are used for the hypothetical prediction of consumer behavior: „Knowledge gained from decades of work in cognitive neuroscience about the mapping between mental process and brain function […] can be leveraged to predict meaningful outcomes beyond the laboratory". Ma, Wang, and Han (2011) investigated in a fMRI study if it is possible to study the Willingness to donate in different socio-economic contexts. For this purpose, probands saw movie scenes while they were in the brain scanner. They showed movie scenes where people were feeling pain. In connection at the fMRI measurement, the subjects were asked to donate money to a charitable donation (see Ma et al., 2011, p.52). The comparison of fMRI data and behavioral data revealed the following: Strong neuronal responses with regard to the pain of others lead to a higher willingness of high socioeconomic status to donate in people. Conversely, the willingness to donate decreases among people with low socioeconomic status (see Ma et al., 2011, p.85).

Furthermore, reference is made to the study by Levy, Lazzaro, Rutledge and Glimcher (2011), which explores the decision-making behavior of consumers. The FMS study focuses on the neural correlates of consumer preferences that exist when the consumer does not have to make a purchase decision. Here, the subjects passively considered images of DVDs, CDs, posters, books, notebooks and lottery tickets (see Levy et al., 2011, p. 119). In addition, for each product presented, subjects should think about a sum of money that they believe reflects the value of the product. During the entire process, the subjects were unaware that they should choose between the products in pairs (see Levy et al., 2011, p.67). The evaluation of the fMRI data confirms the following: Between the product reviews that were created in a "non-choice situation" and the choices made are related.

It should be noted that there is hardly any empirical evidence for products which were identified with fMRT method as success if there is an high demand from consumers in the real market environment (see Ariely & Berns, 2010, p. 288). One exception is the fMRI study by Berns and Moore (2012). The two authors predicted the commercial success of music albums by capturing the neural responses of teens to different songs (see Berns & Moore, 2012, p. 155). Following the empirical investigation, the relationship between the actual sales of the music albums and the neural responses was investigated (see Berns & Moore, 2012, p.218). The data analysis showed that the collected fMRI data predict the sales success of the various songs statistically significant (see Berns & Moore, 2012, p. 158).

Thus, Berns and Moore proved the connection between positive results of the songs in the fMRI examination and the actual market success.

**Review of theories**

As a matter of principle, a novel question should be answered within the framework of an fMRI study, or the study should be designed in such a way that it serves the progress of scientific knowledge. Particularly very useful for the progress of knowledge is the review of competing theories. Ideally, the fMRI study provides important clues as to which theories are valid and, conversely, which theories must be rejected (Huettel & Payne, 2009, p.56). For example, Frydman, Barberis, Camerer, Bossaerts, and Rangel (2014) collected fMRI data to review competing theories of investor behavior. In the study, behavioral finance theory is juxtaposed with neoclassical capital market theory (see Frydman et al., 2014, p. 919). For this purpose, the authors use the fMRI to test hypotheses of the "Realization Utility" model (see Frydman et al., 2014, pp. 331-338). The central assumption of this model is the so-called disposition effect, which describes the tendency of investors to sell higher-value stocks and to retain high-loss stocks (see Kahneman & Tversky, 1984, p 342, Shefrin & Statman, 1985, p 125). The results of the fMRI study largely confirm the assumptions of the "Realization Utility" model, in addition, the findings contradict the assumptions of the neoclassical models[9] (see Frydman et al., 2014, pp. 933, 940). The authors thus provide empirical evidence for the irrational decision-making behavior of investors and cast doubt on the full validity of neoclassical capital market theory.

Furthermore, fMRI studies offer the opportunity to empirically substantiate theoretical constructs. In this respect, fMRI data provides valuable guidance in the selection of constructs. For example, Riedl, Hubert and Kenning (2010a, p. 411) show empirically that the decision as to whether an eBay offer is trustworthy or not activates different brain regions in women and men. Second, the results of their fMRI study illustrate that the decision-making process of women and men differs in digital contexts: to assess the trustworthiness of an eBay offer, female users activate a larger number of brain areas

[9] From the point of view of neoclassical capital market theory, investors act rationally and according to the principle of maximizing utility. In contrast, behavioral finance theory assumes that investors act irrationally and assumes that cognitive and emotional factors influence investor behavior (see Shleifer, 2000, p.117).

than male users (see Riedl et al. 2010a, p. 411-412). This finding implies that women are more likely to seek information than men when shopping online.

Finally, it can be stated that mainly those theories and constructs of consumer behavior should be checked by means of the fMRI, which lacks the neurobiological foundation. The fMRI measurement provides, at best, clues as to how the respective theory of consumer behavior needs to be developed in order to depict the functions of the human brain in a realistic way (see Dimoka, 2012, p.94).

After reviewing the numerous options for defining the research objectives, the next section addresses the two fundamental types of research questions.

### 4.1.2. research questions

In principle, two questionnaire strategies are used within the framework of fMRI studies: on the one hand the question of the "where?" on the other hand, the question of "how?" (see Lorig, 2009, p. 17-18).

**Localization**

If a researcher asks "Where?", the location of activated brain regions is the primary objective of a study. Lorig (2009, p. 18) and Poldrack (2010, P. 755) speak in this context of a functional perspective, since by means of fMRI specific functions of individual brain regions are to be identified. The question of the respective function of a specific brain region is closely connected with the term neuronal correlate (see Shimamura, 2010, p. 774). The term neuronal correlate refers to "a specific pattern of brain activity that correlates with particular conscious experiences "(Rees, Kreiman & Koch, 2002, p. 261). That means brain activities with certain mental processes such as Perception, motivation or learning (see Hubert, Linzmajer, Riedl, Kenning & Hubert, 2012, p. 3).

**Connectivity**

However, the findings described below demonstrate that localization studies do not adequately appreciate the complexity of the brain. Thus, Camerer (2005, p. 16) is unsure that certain neuronal processes are parallel and iterative. Furthermore, there are brain regions involved in several mental processes of the Consumer behavior (see Ariely & Berns, 2010, p.60). Accordingly, many neuroscientists agree that the Question about the "where?" does not bring any great progress of knowledge (see Dimoka, 2012, p.45). It is believed that especially higher ranking cognitive processes (including information processing, remembering) based on a complex interplay of different brain regions (cf. Camerer et al., 2013, p. 247; Smith, K., 2012, p. 25). Here is the research interest especially on the interaction between the individual brain regions. In addition, researchers use fMRI to determine in which order certain brain regions are activated, or even what contribution individual regions make to a mental process (see Smith, K., 2012, p. 51)

Finally, it should be noted that the two types of research questions cannot be strictly separated. The following study by Hubert, Hubert, Riedl and Kenning (2014) on trust in online contexts shows this. Hubert et al. (2014, p. 5) used the fMRI to examine what kind of relationship exists between the perception of trust and the impulsiveness of online shoppers. The assumption that there is a relationship between these two constructs is justified by the authors with previous study results. Hubert et al. (2014, pp. 3-5) used numerous studies to identify the neural correlates of confidence and impulsivity. The cited localization studies also show that those brain regions, that are associated with trust and impulsivity, partially overlap. Building on this, Hubert et al. (2014, p. 5) hypothesizes that trust and impulsiveness leads to a higher willingness of consumers to shop online. It can thus be stated that Hunter developed a new research question ("How do trust and impulsivity work together?"). Since research questions are general and not empirically verifiable, hypotheses are set up in the next step. On the basis of fMRI data, it is possible to check whether the hypotheses agree with reality (see Kuß, 2013, p.94). The following section explains which options are available for hypothesizing in an fMRI study.

### 4.1.3. Hypothesis

Hypotheses are statements about the causal relationship between independent and dependent variables (see Huettel et al., 2014, p. 326). In consumer neuroscience, independent variables include, for example, brand emotions, brand awareness, product and price primacy, or even consumer impulsivity (see Esch et al., 2012, p. 75). In most cases, changes in the BOLD signal represent the dependent variable. Experimental design studies in fMRI studies test a hypothesis by the experimenter, which manipulates the independent variable. If the manipulation of the independent variable does not result in a change in the dependent variable, the hypothesis must be rejected (see Huettel et al., 2014, p.135).

All hypotheses are based on the cause and effect idea, but they decide on their degree of specification: undirected hypotheses are relatively general and merely postulate a connection between independent and dependent variables. Directed hypotheses, describe the relationship of independent variables to dependent variables (see Huettel et al., 2014, p. 326). Establishing an undirected hypothesis requires less prior knowledge than formulating a directed hypothesis. In general, it is advisable to formulate the respective hypothesis as specific as possible. For questions in which an undirected relationship should be clarified, are rarely encountered in research. In addition, a directed hypothesis can be more easily confirmed with the help of the fMRI, if the empirical findings correspond to the hypothetically predicted direction (see Bortz & Schuster, 2010, p.82). In the research literature it is further recommended to use primarily neuroscientific literature and theories for hypothesis development. This ensures that the hypotheses are neurobiologically verifiable (see Cacioppo, Berntson & Nusbaum, 2008, p 67, Dimoka, 2012, p 815). The difference between directional and non-directional hypotheses is discussed below in the studies of Esch et al. (2012) and Karmarkar. The dependent variable represented neuronal activity in certain brain regions and is represented by the BOLD signal. The authors suggest their hypothesis about the interrelationship between the independent and the dependent variables with the following directed hypothesis: The activation in the Wernicke area[10] and in other regions of the information retrieval is higher when consumers process well-known marks (see Esch et al., 2012 , P. 76). As previously announced, the study by Karmarkar et al. (in press, p. 9) set up an undirected hypothesis, roughly as follows: Neuronal activity patterns in the brain, which correlate with the perceived monetary value of a product, differ depending on the order in which product or price information is presented. In this case, the order in which information is presented served as an independent variable. The dependent variable was usual like in other fMRI examinations.

[10] The Wernicke area in the human brain is responsible for the processing of language and in the narrower sense for the processing of brand names (see Esch et al., 2012, p.213)

| | Hypothesis | degree of specificity | Independent variable | Dependent variable |
|---|---|---|---|---|
| **Esch et al. (2012)** | „There will be greater activation of Wernicke's area and other areas of retrieval when consum-ers process familiar (strong and weak brands) than unfamiliar brands" (Esch et al., 2012, S. 76) | directional | brand awareness | BOLD-Signal |
| **Karmarkar/ Shiv/Knutson (in Druck)** | „Activity patterns corre-lated with perceived monetary value in MPFC[14] for purchased and unpurchased prod-ucts differ based on price versus product primacy" (Karmarkar et al., in Druck, S. 9). | undirected | information order | BOLD-Signal |

**Table 3:** Directed versus undirected hypothesis in comparison

### 4.1.4. Interim conclusion

In section 4.1.1. we saw that the options of research objectives illustrate the versatility of fMRI studies. In principle, empirical investigations using the fMRI can be in four different research projects. A conventional research goal of fMRI studies is the (1) generation of meaningful data. Classical methods of observation and questioning are less suitable, for example, for detecting unconscious mental processes (see Aue et al., 2009, p.10). Here, the use of fMRI is particularly justified. Another less common goal of fMRI studies is the (2) validation of scales. A third option is to use fMRI data (3) to forecast future consumers behavior. However, it should be noted critically that there is hardly any empirical evidence for the real market success of products that have been identified as promising in fMRI studies (see Ariely & Berns, 2010, p. 288). The fourth possible goal, (4)(theory review and development) has a particular relevance for consumer neuroscience. The reason for this is that fMRI investigations with this objective enable a high knowledge gain.

Existing theories and constructs of consumer behaviour based on fMRI data can be further developed to be neurobiologically based and to model the actual functioning of the human brain (see Dimoka, 2012, p.815). The goal of the study is concretised by deriving the research question (see Section 4.1.2.). There are basically two types of research questions that can be used as a basis for fMRI studies. On the one hand there are fMRI examinations that answer the question of the "where?". In this case, the fMRI is used to anatomically localize brain functions. The pure (1) localization of brain functions suggests that the complexity of the brain is disregarded. In the research literature it is therefore recommended to ask for the "How?" within the empirical investigation and to investigate with the help of the fMRI the functional connections between certain brain areas. In summary, the results of fMRI studies explore (2) connectivity between different brain areas of higher quality than the results of localization studies. Finally, the research objective and the research question are substantiated by hypotheses (see Section 4.1.3.). There are two types of hypotheses: directional and non-directional. Furthermore, in consumer neuroscience fMRI experiments, the BOLD signal is usually used as a dependent variable. Changes in the BOLD signal can be interpreted as activation of a particular brain region (see Huettel et al., 2014, p. 327). It should be emphasized that the directed hypothesis can be checked more easily with the help of the fMRI (see Bortz & Schuster, 2010, p.288). In addition, it is recommended in the research literature that primarily neuroscientific literature and theories are used for hypothesis development (cacioppo et al., 2008, p 67, Plassmann et al. 2012, p. 32). Table 4 below shows the various design options bundled in the formulation of neuroeconomic issues.

| Aspekte | Optionen | Anwendung / Bemerkungen | Beispielstudien |
|---|---|---|---|
| aim of investigation | Generation of meaningful data | - in unconscious mental processes<br>- on sensitive research topics<br>- at the risk of socially desirable response | Craig/Loureiro/ Wood/Vendemia (2012), Hedgcock/Vohs/ Rao (2012) |
| | validation of scaling methods | - rare | Schaefer/Rotte (2010) |
| | Prediction of consumer behavior | - following fMRI study, forecast is revised based on real market data | Berns/Moore (2012), Levy/Lazzaro/ Rutledge/Glimcher (2011), Ma/Wang/Han (2011) |
| | theory review and development | - great knowledge gain<br>- in competing theories<br>- in theories and constructs without neurobiological foundations | Frydman/Barberis/ Camerer/Bossaerts/ Rangel (2014), Riedl/Hubert/ Kenning (2010a) |
| Research question | Where? Question about the localization | - naive understanding of the human brain | Venkatraman et al. (in Druck) |
| | How? Question about connectivity | - Consideration of complexity | Hubert/Hubert/ Riedl/Kenning (2014) |
| hypotheses | undirected | - Development based on existing neuroscientific theories<br>- little previous knowledge necessary | Karmarkar/Shiv/ Knutson (in Druck) |
| | directional | - Development based on existing neuroscientific theories<br>- sound previous knowledge necessary<br>- better to check with the fMRI | Esch et al. (2012) |

**Table 4:** Design options for the formulation of the neuroeconomic problem

### 4.2. Sketch of the Experimental Design

The second process step is to translate the formulated hypotheses into an experimental design. An important aspect in this context is the choice of stimulus material (see Section 4.2.1.). In addition, the decision on the number of independent variables must be made (see section 4.2.2.). Furthermore, the manipulation of the independent variables is highlighted, or the WithinDesign is compared with the Between design (see Section 4.2.3.). The most important aspect is the choice of the experimental paradigm (see Section 4.2.4.). Finally, it shows how the convergent validity of experimental manipulation (see Section 4.2.5.) can be tested. The section concludes with an overview of all possible design options. 4.2.1.

#### 4.2.1 Stimulation

The fMRI measurement provides the opportunity to present the subjects with different types of stimuli. Conceivable are the visual stimulation, the acoustic stimulation and the olfactory stimulation. Visual stimulation are most frequently presented to subjects, as this type of stimulation is the easiest to perform in the brain. In this case, objects are projected onto an LCD monitor, which is located in the magnetic resonance tomograph. Alternatively, video eyewear is also available for the visual stimulation of the study participants. Video glasses have some advantages over image projection, as they can also be used in people with poor eyesight and allow binocular stimulation Weidner and Fink (2013, p. 314) state that the use of visual stimuli is particularly useful in fMRI studies that explore perception and attention. Simultaneously with the appearance of a randomly selected sign, subjects were asked to direct their attention to the left or right image area or to choose between the two image areas. In addition, words can also be visually presented to the study participants. An example of this is the study by Hoffmann, Mothes-Lasch, Miltner, and Straube (2015, p. 655), which looks at how emotionally charged terms activate different brain regions. For this purpose, Hoffmann (2015, p. 656), the participants in the study, on the one hand, are verbs of physical threat (e.g. murder), on the other hand, they are neutral verbs (e.g. reading). Very common is the use of images as visual stimuli. For example, Zhang, Li, and Pan (2015, p. 417) confronted their study participants with positive image content (e.g., hug), neutral image content (e.g., home appliance), and negative image content (e.g. burned face). The authors sought to identify mechanisms underlying the cognitive processing of affective information (see Zhang et al., 2015, p. 415).

### Acoustic stimulation

Important is also the presentation of acoustic stimuli, which means that the stimulation of participants with the help of sounds or music. Electrostatic or pneumatic headphones[11] are placed on the participants (see Kellermann & Habel, 2013, p.136). In this context, it should be noted that the noise inside the magnetic resonance tomograph is considerable (see Dimoka, 2012, p. 816). Accordingly, it should always be ensured during the measurement that the test person can sufficiently perceive the acoustic stimuli. The application of acoustic stimuli is on the one hand suitable for the induction of emotions in the subjects. On the other hand, acoustic stimuli are used in fMRI studies to investigate processes of perception and information processing (see Meyer, 2013, pp. 349, 353). Koelsch and Skouras (2014, p. 485) presented their subjects with various instrumental pieces in order to show the connection between music and emotions. Happy instrumental pieces were played to evoke joy in the study participants. Horror soundtracks were presented to evoke fear. In addition, neutral instrumental pieces were presented that neither evoke joy nor fear (see Koelsch & Skouras, 2014, p. 3487). Furthermore, Berns and Moore (2012, p. 154) used the fMRI to predict cultural popularity. Here, the subjects heard unknown songs that belonged to the genres Rock, Country, Emo, Indie, Hip Hop, Rap, Jazz, Blues, and Metal. After a song had been played, the Participants should indicate on a rating scale how familiar the song was and how much they liked the song.

### Olfactory stimulation

Somewhat rarer than the visual and acoustic stimulation is the olfactory stimuli. The presentation of smells (see Wang, Sun & Yang, 2014, p. 616). A simple way of olfactory stimulation is the administration of scent samples, which are held in front of the subject's nose. The measurement can be controlled with the help of a so-called olfactometer. This device makes it possible to apply fragrances with constant pressure and constant temperature. Olfactometers are usually outside the magnetic resonance tomograph. The odors are then applied via a long plastic tube that leads into the brain scanner (see Kellermann & Habel, 2013, p.154). The human sense of smell is anatomically and

[11] Stimulation of the eye and the retina

functionally closely linked to the limbic emotion system. For this reason, olfactory stimulation is excellently suited to trigger emotions in the subjects of fMRI examinations (see Moessnang & Freiherr, 2013, p. 54). This fMRI study investigates emotional responses in the brain that occur on scents and trigeminal stimuli[12] (see Benfasi et al., 2013, p.97). Stimulus materials were on the one hand rose and orange fragrance, which are among the olfactory stimuli. In addition, carbon dioxide was used in the study (see Benfasi et al., 2013, pp. 2-3). Carbon dioxide is an odorless gas that is one of the trigeminal stimuli and is perceived by people as tingling. Subjects had the task of evaluating the stimuli for intensity and comfort.

### 4.2.2 Number of independent variables

Following the choice of stimuli, the question arises to the quantity of independent variables. In principle, one can choose between the one-factorial and the multi-factorial design. One-factorial designs are used when an independent variable is at two or more levels. Multi-factorial designs are discussed when more than one independent variable is assumed for the change of the dependent variable (see Kellermann & Habel, 2013, p.168).

**One-Factor Design**

The simplest statistical evaluation method of fMRI data is the so-called subtraction method. Here, phases in which high neuronal activities occur are compared with rest periods (see Jäncke, 2010, p 108, Huettel et al., 2014, pp. 334-335). For this reason, an fMRI experiment should be composed of at least two conditions. This means that the independent variable is varied in two stages. So if there are exactly two conditions, it is called a one-factorial design with two stages. Such a design used, for example, Karmarkar in her investigation. The authors examined the impact of the order in which price and product information is presented on the purchase decision process. For this purpose, the independent variable "order of information" has been varied in two stages. In the decision-making experiment, two conditions occurred in random order (see Karmarkar p. 39): Products were shown to participants (product primacy, Condition 1), then the product were shown along with the assigned price before the study participants should make a purchase decision. Condition 2 provided that the

[12] The trigeminal system of the nasal and oral cavities is responsible for the fact that stimuli are perceived as stinging, biting, prickling, burning or spicy (see Mücke & Lemmen, 2010, p. 44).

subjects first perceive a price primacy, then show a product along with the price before deciding again. It is also conceivable that fMRI studies are based on one-factorial designs that have more than two levels (see Kellermann & Habel, 2013, p. 143). For example, Koelsch and Skouras (2014, p. 86) used a one-factorial three-stage design to study the neural mechanisms that underlie emotion. The participants heard three categories of musical stimulus: (1) joyous instrumental pieces, (2) sad instrumental pieces, and (3) neutral instrumental pieces.

Another application example is the study by Hubert et al. (2014), which examines the impact of trustworthiness on buying decisions in the online context. Hubert et al. (2014, p. 6) based the fMRI study on a one-factorial five-step design. For a stimulus they used product descriptions of eBay offers. The independent variable (trustworthiness of eBay offers) has been varied in five stages. Specifically, five categories of product descriptions were presented to study participants (see Hubert et al., 2014, p.6): (1) no description, (2) claim only, (3) claim + data, (4) claim + data + backing, (5) claim + data + backing rebuttal. There is criticism that the one-factorial design cannot test interaction effects between mental processes (see Amaro & Barker, 2006, p.6). For examination of interaction effects, especially multi-factorial designs are suitable.

**Multi-factorial design**

The simplest form of multi-factorial design consists of two factors, each with two levels. Thus there are two independent ones within the experiment variables that are each varied. This is also referred to as a 2 x 2 design.

An application example is the fMRT study by Dimoka (2010) in the field of trust research. The aim of the study was to investigate whether trust and mistrust represent two independent constructs. Accordingly, in the fMRI experiment trust and mistrust each served as an independent variable; each of the both independent variables should have two levels. Thus, Dimoka (2010, pp. 7-8) relied on a 2 x 2 design.

The following four experimental conditions included: (1) low confidence / low distrust, (2) high confidence / low distrust, (3) low confidence / high distrust, (4) high confidence / high suspicion. To inspire confidence and mistrust, four eBay seller profiles were presented to the subjects as stimuli.

These eBay profiles were manipulated as follows (see Dimoka, 2010, p.8): The first profile contained neither very good nor particularly bad ratings; the second profile contained one hand very good reviews, on the other hand very bad reviews. The third profile was characterized by bad reviews. The fourth profile again contained very bad and very good ratings. It is positive to note that with the help of a multi-factorial design several psychic Processes can be integrated into the fMRI study (e.g. trust and mistrust). Accordingly, this type of design can also be used to provide information about the interaction effects between the psychological processes investigated (see Amaro & Barker, 2006, p. 224; Kellermann & Habel, 2013, p. 143).

### 4.2.3. Manipulation of independent variables

Manipulation of Independent Variables Furthermore, in an fMRI experiment, it is possible to manipulate the independent variable (s) in a within or between design. Within design When using the Within design, all levels of independent variables within a subject group are realized. Thus, each study participant is used as their own control (see Gerrig & Zimbardo, 2008, p.43). An example of the use of the Within design is the study by Esch et al. (2012). The authors manipulated brand awareness in their fMRI study as an independent variable - in addition to brand awareness (see Esch et al., 2012, p.143). In detail, the independent variable brand emotion was present in two stages: strong and weak. Each study participant was presented with highly emotional ("strong") as well as low-emotional ("weak") brands. Between-Design also exists in the experiment the possibility that comparisons between two groups are made. In this case, the between design is used, in which the subjects are exposed to only one experimental manipulation of the independent variable (see Huettel et al., 2014, pp. 325-326). It should be noted that the subjects should be randomly assigned to one of the two groups. This increases the likelihood that the two groups of subjects will be similar in their essential points (see Gerrig & Zimbardo, 2008, p. 123).

One application example is the study by Cole, Yoo and Knutson (2012) in the field of motivational research. The authors reviewed two competing hypotheses in the fMRI study (Cole et al., 2012, p.1): The first assumption is that the processing of complex, dynamic, and multisensory events perceived during a video game leads to an increase in the number of competing hypotheses Activation of the reward system. After the second and competing assumption, active participation in a video game also results in increased activation of the reward system. To examine these hypotheses, the authors divided the study participants into two groups. While one group (active play group) actively participated in the video game, the other group (passive exposure group) merely uninvolvedly watched the progress of the video game. Thus, there is an experimental and a control group. Dimoka (2012, p. 819) recommends using the Within design in fMRI experiments. She justifies her recommendation with the fact that the Within design has a higher test strength than the Between design. However, the Within design also has disadvantages: eg. It should be noted that within-design learning and fatigue effects can occur (see Renner, Heydasch & Ströhlein, 2012, p. 87). A disadvantage of the between design is that the heterogeneity of the subjects can lead to unwanted differences between the two groups. Group differences result u. a. from motion artifacts, d. h., When during the fMRI measurement the study participants of one group move significantly more than the participants of the other group.

If this difference is ignored, the worst case scenario may be a misinterpretation of the fMRI data (see Stöcker & Shah, 2013, p. 173). For this reason, care must always be taken that the data quality is very similar in both groups of subjects.

### 4.2.4. Experimental paradigm

The next step is the design of the experimental paradigm. In this context, the term paradigm refers to the temporal sequence of the stimulus presentation (see Kenning, 2014, p.78). In principle, two different paradigms are used in consumer neuroscience studies: block design and event-related design. In addition, a combination of the two paradigms is possible, the so-called mixed design. In this section the different paradigms are presented, compared and evaluated.

**Block Design**

The block design, which was developed in the early years of fMRI, is also used in current studies (see Huettel, 2012, p. 155). In a prototypical block design, control conditions alternate with experimental conditions (see Huettel, 2012, p. 1153; Kenning, 2014, p. 97): Block A, in which a stimulus is presented, is followed by block B without stimulus presentation. As part of the data analysis (see Section 4.4.), Conditions A and B are subtracted from each other. This makes it possible to identify those brain regions that show stronger hemodynamic reactions during the particular condition. This block design, which uses two different conditions, is called AB block design or alternate design (see

Amaro & Barker, 2006, p.224, Huettel et al., 2014, p.335). Figure 9 shows an alternate block design.). It can be seen that the magnetic resonance measurement is continuously continued during the different phases. Finally, the trace in the lower third of the figure shows that the BOLD signal grows with the magnetic field strength of the scanner.

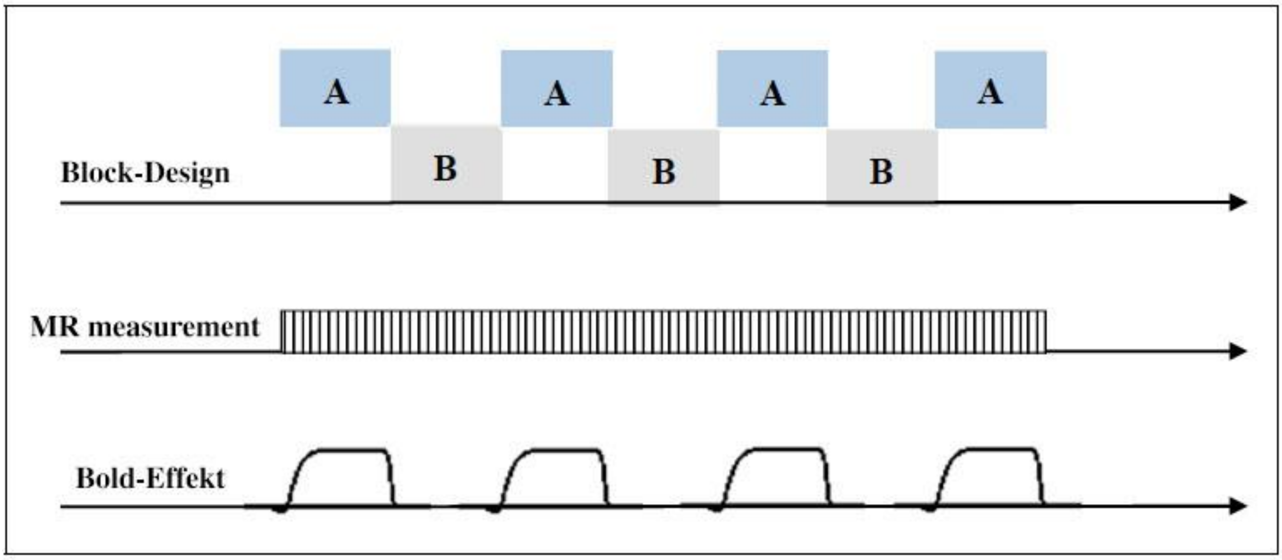


**Figure 9:** Schematic representation of an alternating block design (based on to Amaro & Barker, 2006, p. 224; Weishaupt, 2014, p. 93)

In some cases, it requires the question that the alternating block design is supplemented by the so-called zero-task block C (see Huettel et al., 2014, p. 335, Kenning, 2014, p. 155). These null task blocks are used for control purposes. They make it possible to detect brain activities that occur independently during block A and during block B (see Huettel et al., 2014, p. 335). Furthermore, the question arises as to the duration of the blocks. According to Huettel et al. (2014, p. 335), the temporal length of the blocks varies between 10 and 60 seconds. In general, a block length should not last too long, as this can cause tiredness or boredom in the subjects (see Lindquist, 2008, p. 448). On the other hand, all blocks should have the same length. This simplifies the subsequent statistical analysis of the data. Within a block, only one psychic process is evoked. Accordingly, the stimuli presented to the subject within the block belong to only one condition (see Lindquist, 2008, p. 448). As part of an event-related design, the stimuli can be used more flexibly, as illustrated in the following text section.

**Event-related design**

The event-related design is based on the assumption that the activation of brain regions occurs at short intervals. Stimuli or stimuli, called events in this context, evoke such activations (see Kenning, 2014, p.312). Against this background, the event-related design is suitable for mapping the temporal sequence of activations of different brain regions (see Huettel, 2012, p. 1154). Characteristic of the event-related design is the flexible arrangement of the stimuli. In contrast to the block design, the stimuli are presented individually instead of showing them to the test person over a longer period of time (block). Also, it is not determined before the experiment, at which time a stimulus occurs. Furthermore, the charms are presented only very briefly. So that the stimuli cannot be anticipated by the subjects, they are randomized (see Liu, 2012, p. 1158). Thus, each stimulus is statistically independent of previous stimuli (see Kellermann & Habel, 2013, p. 140; Kenning, 2014, p. 101). In most event-related designs, the different conditions of the independent variables are represented by means of different events. The pause period between two events marks the so-called interstimulus interval (see Huettel et al., 2014, pp. 349-350). Typically, the experimenter varies the length of intervals between two events, as this can increase the meaningfulness of the experiment (see Clark, 2012, 1190, Kellermann & Habel, 2013, p.163). The variation of interstimulus intervals at random is referred to in the literature as "jittering" (Kenning, 2014, p. 102). In principle, the time duration of interstimulus intervals is between four and six seconds. Figure 10 below illustrates once more the principle of EventRelated design. It can be seen that different types of stimuli (laughing faces versus car brands) are presented in random order to the subject. In this way it can be investigated if and how the neural activation differs when looking at faces and car brands.

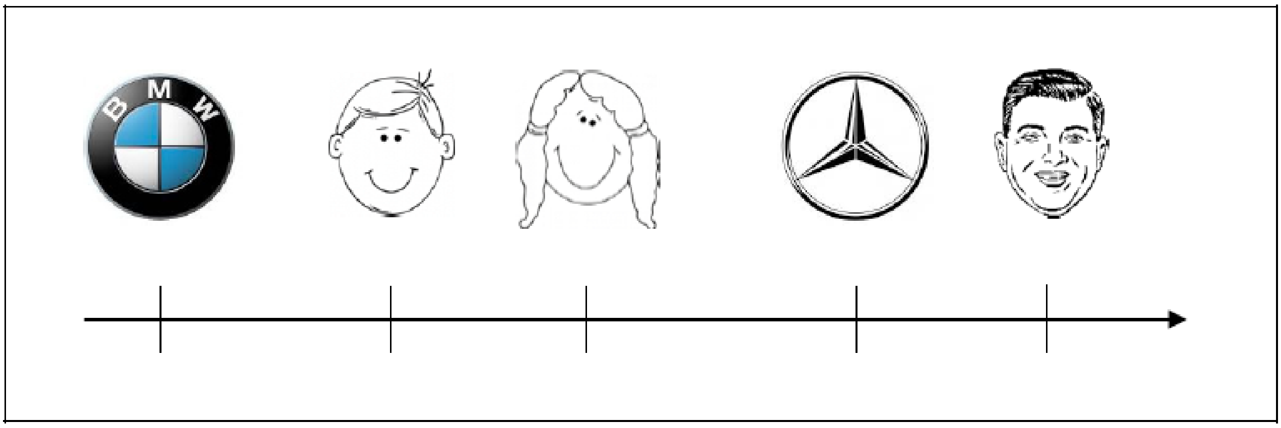

**Figure 10:** Principle of event-related design (see Kenning, 2014, p. 101)

Mixed design in addition to the block and the event-related design, the use of a hybrid design form, the mixed design, is also possible. In such a mixed design, the stimuli are presented in blocks, but each block contains different types of events (see Petersen & Dubis, 2012, p. 1177).

Following the characterization of the block and event-related design, it follows a brief overview of the advantages and disadvantages of the two design form. The biggest advantage of the block design is that it has a high test strength (see Caria, Sitaram & Birbaumer, 2012, p.490, Lindquist, 2008, p.448). The so-called test strength describes the sensitivity of an examination to correctly identify an actual effect of a certain size (see Bortz & Schuster, 2010, p.81). In this context, it should be noted that the block design is often used to identify activated brain regions. It can be concluded that this design form is suitable for fMRI studies perfectly aimed at the localization of a particular mental process (see Huettel, 2012 S. 1154;). Furthermore, the block design is easy to design; It impresses with its simplicity in data analysis and interpretation (see Kellermann & Habel, 2013, p. 541). Less suitable is the block design for questions that focus on the temporal course of a mental process. Also, individual aspects of a process. As the decoding or information retrieval in the context of information processing, cannot be examined by means of a block design (see Huettel et al., 2014, p 344). Another disadvantage of block designs is that they can cause fatigue in the probands. This is especially the case with challenging tasks that span a longer period of time. In addition, learning effects can falsify the examination result, because - in contrast to the event-related design - the stimuli are not presented randomly. The presentation of the stimuli within the blocks is z. It is therefore predictable that subjects can acquire knowledge about the order of the stimuli (see Clark, 2012, p. 1192). This jeopardizes the internal validity[13] of the empirical investigation using the fMRI. In contrast to the block design, a larger range of questions can be answered with the help of the event-related design. Thus, conclusions can be made regarding the time course of a neuronal activity, with regard to the functional cross-linking between different brain regions and with regard to long-lasting activation (see Huettel et al., 2014, p.98). The event-related design is also suitable for experimental arrangements that are controlled by the test subjects. In summary, this design allows much greater flexibility in the placement of the stimuli. A disadvantage in this context is that the increase in flexibility makes data analysis extremely complex (see Huettel, 2012, p. 1153). The benefits of event-related designs mentioned led in recent years to the fact that the block design became less important for neuroscience research, "And, as event-related methods have become ubiquitous, they no longer represent a distinct category of fMRI research. In a real sense, event-related fMRI has now become, simply, fMRI "(Huettel, 2012, p. 1152). Also in the consumer neuroscience, neuro-Finance, Organizational

[13] According to Bortz and Döring (2006, p. 53), the internal validity of an empirical study is given when changes in the dependent variables are clearly attributable to the influence of the independent variables. The internal validity decreases if there are additional plausible alternatives - such as: B.
Learning effects - for changes in the dependent variables.

Neuroscience, neuro-accounting and neuro-IS were in A + - and A-journals, between 2010 and 2015 almost exclusively fMRI studies published that use the event-related design , Table 5 below gives an overview of the fMRI studies published from 2010 to 2015 and their design paradigms. It is striking that of the 22 studies listed, only three are based on a block design. Six other studies did not show the design paradigm. A total of studies is based on an event-related design.

| Authors | Design |
|---|---|
| **Consumer Neuroscience** | |
| Bagozzi et al. (2012) | |
| Berns/Moore (2012) | |
| Cascio/O'Donnell/Bayer/Tinney/ Falk (in Druck) | |
| Craig/Loureiro/Wood/Vendemia (2012) | Event |
| Esch et al. (2012) | Event |
| Hedgcock/Vohs/Rao (2012) | Block |
| Karmarkar/Shiv/Knutson (in Druck) | Event |
| Reimann/Castaño/Zaichkowsky/ Bechara (2012) | |
| Rei-mann/Zaichkowsky/Neuhaus/Bender/Weber (2010) | |
| Venkatraman et al. (in Druck) | Event |
| **Neuro-Finance** | |
| Bruguier/Quartz/Bossaerts (2010) | |
| Fryd-man/Barberis/Camerer/Bossaerts/Rangel (2014) | |
| **Organizational Neuroscience** | |
| Hytönen et al. (2014) | Event |
| **Neuro-Accounting** | |
| Barton/Berns/Brooks (2014) | Event |
| Farrell/Goh/White (2014) | Block |
| **Neuro-IS** | |
| Anderson/Vance/Kirwan/Eargle/ Howard (2014) | Event |
| Benbasat/Dimoka/Pavlou/Qiu (2010) | Event |
| Dimoka (2010) | Event |
| Hubert/Hubert/Riedl/Kenning (2014) | |
| Hu-bert/Linzmajer/Riedl/Kenning/Hubert (2012), Riedl/Hubert/ Kenning (2010a) | Event |
| Kopton/Sommer/Winkelmann/ Riedl/Kenning (2013) | Event |
| Riedl/Mohr/Kenning/Davis/Heekeren (2011), Riedl/Mohr/Kenning/ Davis/Heekeren (2014) | Event |

**Table 5:** Design paradigms used in consumer neuroscience fMRI studies Neuro-Finance, the Organizational Neuroscience, the Neuro- Accounting and Neuro-IS in the period 2010 to 2015

### 4.2.5. Convergent validation

Finally, once all decisions regarding the experimental design have been made, the convergent validity of the experimental manipulation can be verified. Convergent validity is a component of construct validity and is given in an experiment if different operationalizations of the same mental construct lead to the same results (Campbell & Fiske, 1959, p.81, Manstead & Livingstone, 2014, p.114). In a fMRI study, convergent validity is generally assessed in two ways: One common approach is to (1) perform a behavioral experiment in parallel to the fMRI experiment. Subsequently, the data analysis is used to test whether the fMRI measurement results and the results of the behavioral experiment correlate. Another approach is to (2) use a psychophysiological procedure or another imaging modality in parallel to the fMRI measurement. The measurement results of the two experiments are also correlated with each other. An example of this is the study by Kopton et al. (2013), which focuses on building trust in social networks. In the study, both a behavioral and a fMRI experiment were conducted to understand the role of images and texts in building trust and networking in social networks (see Kopton et al., 2013, pp. 1-6). Also, Reimann et al. (2010) used both a behavioral and an fMRI experiment to test the hypotheses presented in their empirical study (see Reimann et al., 2010, p. 432). The aim of the study was to determine the psychological and neural mechanisms of aesthetic packaging design. Complementary Measurement Using Psychophysiological or Imaging Techniques It is somewhat costlier to perform the same experiment not only using the fMRI, but in addition to another psychophysiological or imaging procedure. A current example is the study by Venkatraman et al. (in print) to forecast advertising success. To capture respondents' responses to 30-second commercials, Venkatraman et al. in addition to the fMRT u. a. eye tracking, skin resistance measurement, electrocardiogram and EEG as additional measurement methods. "The experimental protocol was largely identical, except for minor methodology-specific modifications", Venkatraman et al. (in press, p. 15). Thus, apart from small deviations, the structure and procedure of the experiment were the same for each individual data collection. Since in the case of the mentioned study presumably high costs for equipment and research personnel are incurred, it would have to be examined whether the multiple method use is justified.

### 4.2.6. Interim conclusion

As in section 4.2.1. explains, there are several options of stimulus application when performing a fMRI experiment. Easy handling makes the application of visual stimuli stand out. Visual stimuli can be in form of a picture, words or signs. They are primarily used in fMRI studies that investigate processes of perception or the construct of attention (see Kellermann & Habel, 2013, p. 32). Weidner & Fink, 2013, p. 314). Another possibility is to present to the test persons acoustic stimuli in the form of music or sounds. In this context, it should be noted that the interior of the brain scanner has a considerable noise level, which may possibly impair the perception of the acoustic stimuli (see Dimoka, 2012, p. 816). In principle, acoustic stimuli are suitable for the induction of emotions, for the investigation of processes of perception and information processing (see Meyer, 2013, pp. 349, 353). Somewhat rarer than the visual and acoustic stimulation is the presentation of olfactory stimuli, the presentation of odours. Since the human sense of smell is anatomically and functionally closely linked to the limbic emotion system, olfactory stimulation is eminently suitable for inducing emotions (see Moessnang & Freiherr, 2013, p. 514). The decision for a one- or multi-factorial design (see Section 4.2.2.) depends on the research question. One-factorial designs are called when there is an independent variable; In multi-factorial design, the influence of two or more independent variables on the dependent variable is examined. The intention is to investigate the interaction effects between two psychic processes by means of the fMRI, the use of a multi-factorial design (compare Amaro & Barker, 2006, p. 224). In addition, experimenters have various options for manipulating independent variables (see Section 4.2.3.). On the one hand, there is the Within design, in which all stages of the independent variables within a group of probands are realized. On the other hand, there is the between design, in which the subjects are only exposed to an experimental manipulation of the independent variables. The use of Within design in fMRI studies is testament to its high test strength (see Dimoka, 2012, p. 819). On the other hand, the learning and fatigue effects that arise within the WithinDesign can have a negative impact on the measurement results (Renner et al., 2012, p. 87). Should the research question of the fMRT study require the use of a between design, the data quality should be equally good in both groups of volunteers. Finally, to answer the research question, a suitable design paradigm must be selected. Two basic design types are the block design and the event-related design (see Section 4.2.4.). The block design is characterized by a relatively rigid experimental design. Prototypically, control conditions alternate with experimental conditions (see Huettel, 2012, p. 1153). The high test strength of the block design and its excellent suitability for localizing neuronal activity are positive (see Huettel, 2012, p 1154, Petersen & Dubis, 2012, p. 1178). In addition, this design form is easy to handle; the block-design fMRI data is easy to analyse and interpret (see Kellermann & Habel, 2013, p.233). However, some subjects show fatigue in block designs or anticipate the order of stimuli (see Clark, 2012, p. 192). A remedy in this context is the Event-related design, which enables a much more flexible experimental design. In contrast to the block design, the stimuli are presented individually, randomly and only briefly (see Liu, 2012, p. 158). Furthermore, this design form can be used to address a broader range of questions: it is possible to study the time course of a neuronal activity or to investigate the networking of different brain regions.

However, the event-related design requires the experimenter great methodological knowledge with regard to the complex data analysis (see Huettel, 2012, p.153). Section 4.2.5. Finally, he showed how the convergent validity of experimental manipulation can be verified. In general, experimenters have the opportunity to conduct a behavioral experiment parallel to the fMRI experiment.

This additional collection of data is reported by Yoon et al. (2009, p. 16) are explicitly recommended for investigations of consumer neuroscience. In addition, a psychophysiological or other imaging modality may be used in addition to the fMRI, but this may significantly increase the cost of the proposed study Table 6 below summarizes the referenced and evaluated design options to consider when designing the experimental design.

| Aspects | options | application / Remarks | example studies |
|---|---|---|---|
| Stimulation | visually | - stimuli in the form of signs, words, pictures<br>- good usability<br>- to study the perception, attention | Bengson/Kelley/ Mangun (2015), Hoffmann/ Mothes-Lasch/ Miltner/Straube (2015), Zhang/Li/Pan (2015) |
| | acoustically | - stimuli in the form of sounds, music<br>- compete with loud scanner sounds<br>- to study emotional processes, perception, information processing | Koelsch/Skouras (2014), Berns/Moore (2012) |
| | olfactory | - to study emotional processes<br>- stimuli in the form of fragrance samples | Bensafi et al. (2013) |
| number of independent variables | one-factorial design | - Integration of a single mental process in fMRI scan | Kamarkar/Shiv/Knutson (in Druck), Koelsch/Skouras (2014), Hubert/Hubert/Riedl/ Kenning (2014) |
| | multifactorial design | - Integration of multiple mental processes in the MRI scan<br>- Research on interaction effects possible | Dimoka (2010) |
| manipulation of independent variables | Within-Design | - high test strength<br>- danger of learning and fatigue effects | Esch et al. (2012) |
| | Between-Design | - relatively low test strength<br>- different data quality in subject groups | Cole/Yoo/Knutson (2012) |

| | | | |
|---|---|---|---|
| **experimental paradigm** | Block | - high test strength<br>- suitable for the localization of neuronal activity<br>- simplicity of conception, data analysis, interpretation<br>- Gafahr of fatigue and learning effects | u.a.<br>Bagozzi et al. (2012), Hedgcock/Vohs/Rao (2012) |
| | Event-Related | - flexible arrangement of the stimuli<br>- Investigation of the temporal course of neuronal activity and functional networking between brain regions<br>- complex data analysis | u. a.<br>Riedl/Mohr/Kenning/ Davis/Heekeren (2014), Venkatraman et al. (in Druck) |
| **convergent validation** | Supplementary behavioral measurement | - Recommended especially for MRI examinations of Consumer Neuroscience<br>- relatively easy to implement | Kop-ton/Sommer/Winkelman n/Riedl/Kenning (2013), Reimann/Zaichkowsky/ Neuhaus/Bender/Weber (2010) |
| | Complementary psycho-physiological / imaging measurement | - additional costs | Venkatraman et al. (in Druck) |

**Table 6:** Design options

### 4.3. Selection of subjects

This section shows the various options available when recruiting subjects. Relevant criteria are u. a. the intelligence, the handedness, the age and the gender of the subjects. In the following, emphasis will be placed on the aspects of old age (see section 4.3.1.) And gender (see section 4.3.2.), As these two criteria will be prioritized in research practice in order to acquire suitable subjects. Finally, it explains which advantages and disadvantages are associated with large and small sample sizes (see Section 4.3.3.). Finally, an interim conclusion will provide a brief overview of the illuminated design aspects.

#### 4.3.1. Age

Requirement for a well-founded fMRI study is the careful selection of subjects. With regard to the age of the study participants, two selection strategies can be pursued: The first possibility is to recruit subjects from all age groups (heterogeneous age structure). The second possibility represents the acquisition of subjects of comparable age (homogeneous age structure).

**Homogeneous age structure**

In principle, homogeneous groups of probands are advised in fMRI experiments (see Yarkoni &

Braver, 2010, pp. 87-88). The advantage of groups of subjects with a homogeneous age structure is that age-specific effects, which should be taken into account when interpreting the measurement results, are eliminated. The disadvantage of using samples with a homogeneous age structure is that individual differences between individuals can not be explored in the context of the fMRI examination (see Yarkoni & Braver, 2010, p. 64). Furthermore, in homogeneous samples, the study results are only conditionally transferable to the heterogeneous general public. Against this background, the generalizability of fMRI studies is often questioned (see Costafreda, 2009, p.5, Hubert & Kenning, 2011, p.219, Yarkoni & Braver, 2010, p.88). Third, when using a homogeneous sample, the representativeness of the study results is limited.

**Heterogeneous age structure**

The use of a sample in which all age groups are represented suggests, first and foremost, that the human brain changes with age. First, it is thought that the coupling between neuronal activity and BOLDSignal behaves differently in old age and can thus distort the measurement results (see D'Esposito, Deouell & Gazzaley, 2003, p.83). The cause of this change is the diminishing elasticity of blood vessels in the elderly and atherosclerosis. Furthermore, with increasing age, anatomical deformations of the brain occur. For example,. For example, older people's brain surface has greater unevenness than that of younger subjects, which should be taken into account in data analysis (D'Esposito et al., 2003, p.867).

### 4.3.2. Gender

Furthermore, the decision for or against a mixed-gender sample is made in the context of the subject selection. In any case, it should be remembered that neuroscience research has found differences in the function of the male and female brain in recent years. To give an insight into this topic, the following are some recent fMRI studies that show gender differences in the activating and cognitive processes of consumer behavior. Spalek et al. (2015) examined the gender-specific processing of emotions. The fMRI data showed that men and women react differently to negative image scenes. In general, when viewing negative image contents, the female brain is activated more strongly, in particular motor-relevant brain regions and the posterior cingulate cortex having a higher activation (see Spalek et al., 2015, p 932). Kohn, Kellermann, Gur, Schneider, and Habel (2011) point out gender-related differences in the cognitive processing of humor. The results of the fMRI study show that in female brains, emotional perception is predominantly active in female brains, whereas in male brains, emotional regulation is active.

In addition, Riedl et al. (2010a) to identify differences between man and woman in the neural emergence of trust. The findings of the FTS study show that the female brain has a more active activity than the male brain in the assessment of trustworthiness (see Riedl et al., 2010a, pp. 411-412). This result implies that women make more differentiated decisions of trust. Another fMRI study by Lighthall et al. (2012) addressed the question of whether male and female decision-making behavior differ in stressful situations. The authors discovered that an elevated stress level leads to unfavorable decisions in men. In addition, men who are exposed to stress become more careless in their decision-making behavior. In women, the opposite effect is seen (see Lighthall et al., 2012, p. 482). There are also gender differences concerning information acquisition, processing and storage. For example, a meta-study by Herlitz and Lovén (2013) shows that women are better at recognizing faces than men. Furthermore, Banks, Jones-Gotman, Ladowski and Sziklas (2012) showed by means of an fMRI study that clear activation differences exist between male and female brains when information is decrypted or recognized. The explanations make it clear that special attention should be given to gender effects in mixed-gender samples. These can ultimately lead to a gender-specific distortion of the fMRI measurement results. In order to exclude a distortion from the outset, it is appropriate to limit the fMRI examination to male or female subjects.

### 4.3.3. Sample size

A challenge of fMRI examinations is the determination of the necessary sample size. Typically, specifying the sample size is heavily influenced by practical considerations. For example, the amount of costs per scanner hour and the availability of suitable study participants play a role in the preliminary considerations (Barton et al., 2014, p. 1951).

Small Sample

The use of small samples in consumer neuroscience fMRI studies has been criticizing the scientific literature for years (see Bennett & Miller, 2010, p.143, Poldrack, 2012, p. P. 1217). An immediate consequence of small samples is that it reduces test strength (see Button et al., 2013, p. 365); Guo et al., 2014, p. 172). The so-called test strength describes the sensitivity of an examination to correctly identify an actual effect of a certain size (see Bortz & Schuster, 2010, p. In some cases, small sample sizes also lead to false positive results18 and increase the likelihood of committing a type II error19 (see Carp, 2012, p.11; Yarkoni, Poldrack, Van Essen & Wager, 2010, p. 490). Button et al. (2013, p. 368) also note that fMRI studies with too small a number of cases often show further quality deficiencies. The authors suggest opportunistic motivations behind conducting such studies and suggest that not only in the determination of the sample size but also in the data collection and analysis is careless.

**Large sample size**

Nonetheless, the use of a sufficiently large sample size is often difficult to achieve for cost-effectiveness reasons. On the one hand, high costs are incurred for each scanner hour (see Section 3.1.2.); on the other hand, more research personnel are needed to conduct large-scale fMRI studies

**Sample Size Selection Guidelines**

There are few guidelines in the literature for choosing the sample size. For example, Ariely and Berns (2010, p. 292) recommend a sample size of at least 30 subjects. According to Murphy and Garavan (2004, p. 885) and Thirion et al. (2007, p. 117) 27 subjects are already sufficient for a fMRI examination. A larger sample size only brings a marginal gain in test strength. Huettel et al. continue to note that the use of large samples is not always necessary. The authors are of the opinion that a smaller sample is sufficient for fMRI examinations, which, for example, investigate perceptual processes (see Huettel et al., 2014, p. 275). The situation is different in fMRI studies that investigate group differences (see the discussion of the between design in 4.2.3.). In this case, the choice of a large sample is recommended. Because the smaller the sample size, the lower the test strength, significant differences between two groups of subjects to discover (see Ariely & Berns, 2010, p 292, Button et al., 2013, p 369, Huettel et al., 2014, P. 275). Likewise, fMRI studies that explore higher-ranking cognitive processes or focus on individual differences between subjects require comparatively large random samples (see Huettel et al., 2014, p. 275). Those already described in section 4.2.4. The fMRI studies published in A + and A journals published between 2010 and 2015 were also screened with regard to the number of test persons, the gender and the age structure of the subjects (see Table 7 below). It is noticeable that the target sample size of 30 or 27 subjects is undercut in 17 of a total of 22 studies. In addition, there are hardly any same-sex samples. The average age of the subjects is - across all studies considered - between 14.6 and 34.4 years. Thus, in terms of age, relatively homogeneous samples are available. Furthermore, it can be stated that the involvement of older brains in the fMRI examinations is avoided. Information on the age range and the standard deviation are unfortunately only incomplete.

| Authors | proband number | female | age (mean) | age span | standard deviation |
|---|---|---|---|---|---|
| **Consumer Neuroscience** | | | | | |
| Bagozzi et al. (2012) | 24 | 8 | 34,4 | | 6,13 |
| Berns/Moore (2012) | 27 | 14 | 14,6 | 12-18 | k. A. |
| Cascio/O'Donnell/Bayer/Tinney/Falk | 65 | 0 | 16,9 | 16-17 | 0,3 |
| Craig/Loureiro/Wood/Vendemia (2012) | 26 | | | | k. A. |
| Esch et al. (2012) | 15 | 0 | | Twens | k. A. |
| Hedgcock/Vohs/Rao (2012) | 16 | 9 | 27,4 | | 9,0 |
| Karmarkar/Shiv/Knutson (in Druck) | 17 | 9 | | 19-27 | |
| Reimann/Castaño/Zaichkowsky/Bechara (2012) | 16 | 8 | | | |
| Reimann/Zaichkowsky/Neuhaus/Bender/Weber (2010) | 17 | 9 | | | |
| Venkatraman et al. | 33 | 15 | 29 | 21-37 | |

| | | | | | |
|---|---|---|---|---|---|
| **Neuro-Finance** | | | | | |
| Bruguier/Quartz/Bossaerts (2010) | 18 | | | | |
| Frydman/Barberis/Camerer/Bossaerts/Rangel (2014) | 28 | 6 | 25,6 | 18-60 | 7,6 |
| **Organizational Neuroscience** | | | | | |
| Hytönen et al. (2014) | 19 | 10 | 22,1 | | 2,2 |
| **Neuro-Accounting** | | | | | |
| Barton/Berns/Brooks (2014) | 35 | 8 | 28 | | |
| Farrell/Goh/White (2014) | 24 | 0 | | | |
| **Neuro-IS** | | | | | |
| Anderson/Vance/Kirwan/Eargle/Howard (2014) | 22 | | | | |
| Benbasat/Dimoka/Pavlou/Qiu (2010) | 24 | 12 | | | |
| Dimoka (2010) | 15 | 6 | | | |
| Hubert/Hubert/Riedl/Kenning (2014) | 20 | 10 | 31,8 | 30-35 | 1,73 |
| Hubert/Linzmajer/Riedl/Kenning/Hubert (2012), Riedl/Hubert/ Kenning (2010) | 20 | 10 | 31,9 | 30-35 | |
| Kopton/Sommer/Winkelmann/Riedl/Kenning (2013) | 20 | 9 | 25,6 | | 3,24 |
| Riedl/Mohr/Kenning/Davis/Heekeren (2011), Riedl/Mohr/Kenning/Davis/Heekeren (2014) | 18 | 7 | 31,83 | 25-40 | 4,14 |

**Table 7:** Characteristics of the subjects in fMRI studies of Consumer NeuroscienceNeuro-Finance, the Organizational Neuroscience, the Neuro-Accounting and Neuro-IS in the period 2010 to 20154.3.4. interim conclusion

Section 4.3.1. explained that subjects can be recruited on the one hand from different age groups, on the other hand from the same age group. A homogeneous age structure of the subjects offers the advantage that age-specific effects are eliminated.The disadvantage is that homogeneous groups of subjects are not suitable for researching individual differences (see Yarkoni & Braver, 2010, p. Furthermore, homogeneity leads to a lack of generalizability and representativeness of the study results (see Costafreda, 2009, p.5, Hubert & Kenning, 2011, p.219, Yarkoni & Braver, 2010, p.88). A very serious disadvantage of a heterogeneous age structure is that the human brain changes with age: a change in the BOLD signal and the brain shape are the result. This must be taken into account in the context of data analysis. In addition to age, the sex of the subjects (see Section 4.3.2.) Is an important selection criterion. It should be noted in this context that there are differences in the function of female and male brains. These differences are u. a. Evidence from fMRI studies on emotion processing, humor, trust decisions, decision-making in stressful situations, and information acquisition, processing, and storage (see Banks et al., 2012, Herlitz & Lovén, 2013, Kohn et al

Lighthall). In summary, it can be concluded that special attention should be given to gender effects in mixed-gender samples. In order to exclude a distortion of the measurement results from the outset, a same-gender sample should always be considered. The challenge of determining the necessary sample size was discussed in Section 4.3.3. described. In principle, it is always advisable to use large-scale samples in fMRI experiments, as this ensures adequate test strength. For economic reasons, however, large samples are often unrealizable.

Finally, as a guideline for fMRI examinations, a sample size of 27 or 30 persons is recommended (see Ariely & Berns, 2010, p 292, Murphy & Garavan, 2004, p 885, Thirion et al., 2007, p. 492). To investigate processes of perception, a smaller number of subjects is sufficient (see Huettel et al., 2014, p. 275). Table 8 below summarizes the design options available for subject selection in terms of age, gender, and sample size.

| Aspects | Options | Remarks | Example studies |
|---|---|---|---|
| Age | Sample with homogeneous age structure | - no age-specific effects<br>- lack of generalizability and representativeness of study results | Hubert/Hubert/ Riedl/Kenning (2014), Hytönen et al. (2014) |
| | sample with heterogeneous age structure | - no age-specific effects<br>- lack of generalizability and representativeness of study results | - |
| Gender | same-sex sample | - no distortion of the results | Esch et al. (2012), Farrell/Goh/White (2014) |
| | mixed gender sample | - gender-specific effects possible by distortion of the measurement results | Bagozzi et al. (2012), Kamarkar/Shiv/ Knutson (in Druck) |
| Sample size | Small | - cost effective<br>- low test strength<br>- Danger of type 1 and type 2 errors<br>- Minimum number of subjects = 27-30; is often fallen short of in reality | Esch et al. (2012), Hedgcock/Vohs/Rao (2012) |
| | Big | - high costs<br>- relatively high test strength | Barton/Berns/Brooks (2014), Cascio/O'Donnell/Bayer/ Tinney/Falk (in Druck), |

**Table 8:** Design options for the selection of subjects

## 4.4. Analysis of the data

This section describes two basic options of fMRI data analysis: functional specialization (see Section 4.4.1.) And functional integration (see 4.4.2.). The section concludes with an overview of the discussed design aspects. While the concept of functional specialization assumes that local brain regions are specialized in specific functions, functional integration is based on the idea that higher brain functions are the result of the cross-linking of different brain regions (Friston, 1994, p. These concepts have already been discussed in Section 4.1.2. to clarify the two basic types of research questions - the question of localization and connectivity.

### 4.4.1. Functional specialization

The evaluation of the fMRI data can take place on several levels: One possibility is to carry out one (1) individual analysis. This form of analysis is also called "First Level" analysis in the research literature. The second possibility is to carry out a (2) group analysis (also: "second level" analysis) (see Dimoka, 2012, p. 830). A third form of analysis that focuses only on parts of the brain is the (3) Regions Of Interest (ROI) analysis. Single analysis The single analysis is preceded by the specification of the General Linear Model (ALM). The ALM is used to explain the BOLD waveform and is expressed by a regression equation. The model specification takes into account information that emerges from the previously designed experimental design: Specifically, the ALM is determined by the number of different conditions, their temporal arrangement, and the BOLD signal (Kenning, 2014, p & Kellermann, 2013, pp. 158-159). The example of the study by Esch et al. (2012) below shows how an ALM can be specified. The cited study differentiates between two levels of the factor brand emotion: In detail, the subjects were presented with highly emotional as well as unknown brands (see Esch et al., 2012, p.43). Thus, there are two experimental conditions that serve as regressors in ALM. Based on this information, the ALM can be set up as follows:

Here, y stands for the empirically observed values of the voxel time series. ٻ is the regressor for highly emotional brands, ٻ is the regressor for unknown brands. The rest condition, ie the situation in which neither of the two conditions is present, is implicitly modeled here. Thus, the rest condition corresponds to the constant c. Finally, ε is the residual error term. In short, the ALM describes the relationship between the activations measured in the respective voxels and the experimental conditions. Subsequent to the model specification, the regressors can be summarized in the so-called design matrix. Based on the design matrix, the unknown regression parameters are finally estimated before the actual single analysis begins (see Dimoka, 2012, p 830). In the context of the individual analysis, sample-specific contrast images20 are calculated in order to represent separately the activation differences between the experimental conditions for each person (see Huettel et al., 2014, p. 385). Subsequently, additional statistical tests should be carried out to check whether the measured activation differences are statistically significant (see Huettel et al., 2014, pp. 366-368). Depending on the question, it may make sense to expand the statistical evaluation and to supplement the individual with a group analysis. An example of this is the fMRT study by Dimoka (2010), which explores whether trust and mistrust are two independent constructs. The author carried out both a single and a group analysis (see Dimoka, 2010, p. 384).

**Group analysis**

A prerequisite for successful group analysis is that the individual images of the subject brains are adapted to a standardized standard brain. This process is called normalization. The process of normalization ensures the comparability of the subject brains, although these differ in shape and size in reality (see Dimoka, 2012, p 827, Kellermann & Habel, 2013, p. 156; Kenning, 2014, p. 107). The actual group analysis uses the sample-specific contrasts from the individual analysis to analyze them on a second level. The advantage of group analyzes is that statements can be made about the entirety of the studied study participants. Accordingly, the study results show a higher generalizability. One disadvantage is that the data must first be prepared by adapting the subject brains to a standardized standard brain (see Huettel et al., 2014, p. 397).

**ROI analysis**

According to Kenning (2014, p. 109), the ROI analysis "describes the investigation of a or multiple predefined brain regions ". From this definition, it can be concluded that the use of an ROI analysis is particularly useful if an fMRI study contains hypotheses on activation differences in specific brain regions.

In order to determine the ROIs of interest or the specific brain regions, a neuroeconomic issue must first be determined in the planning phase of an fMRI study. Subsequently, neuroscientific studies are looked at, which are based on a similar question. Those brain structures that were identified in the already published fMRI studies then form the basis for the newly defined ROIs (see Kenning, 2014, pp. 110-111). So far, ROI analysis in consumer neuroscience fMRI studies has not used too often (see Kenning, 2014, p.89). However, there is a recent study by Venkatraman et al. (in print) in which an ROI analysis was performed as part of the data analysis. The authors (in press, pp. 13-14) determined four ROIs in total: For example, the authors suspected increased activation in the amygdala for emotion processing, increased activation in the dorsolateral prefrontal cortex for attention, and increased activation for memory increased activation in the ventral striatum in the hippocampus as well as for the perception of desire.

Poldrack (2007, pp. 67-68) mentions two basic benefits of ROI analysis: First, by limiting the fMRI measurement to a few brain regions, the ROI analysis could be used to provide statistical control of the alpha-error analysis.

Probability to be used. Second, the ROI analysis is useful for the simplified evaluation of complex experimental designs that, for example, have many different conditions. Here, small ROIs are determined by the maxima of the various brain clusters. In this way, activation differences between different experimental conditions can be compared in a simplified manner. The problem is that the ROI analysis is also based on the idea of localization (see Section 4.1.2.): In principle, there is a danger that certain brain functions and certain brain regions will be wrongly assigned to each other and thus worthless as ROIs (see Huettel, 2014, p. 395).

### 4.4.2. Functional integration

As at the beginning of section 4.4. The concept of functional integration is based on the idea that most mental processes result from a complex interplay of different brain regions (Camerer et al., 2013, p. 247), two forms of functional integration can be distinguished: the (1) functional connectivity and the (2) effective connectivity.

#### Functional connectivity analysis

The functional connectivity analysis attempts to establish a correlation between the signal strands of two brain regions (see Wohlschläger & Kellermann, 2013, p. 166). The prerequisite for conducting a functional connectivity analysis is that the neuronal activities of two brain regions A and B lead to a BOLDSignal. If this is the case, the fMRI can be used to record signal time histories of both regions. To study the dependence between the two signal strands, the Pearson correlation coefficient can be used in the next step. If the two signal strands are correlated, a functional connectivity between brain regions A and B can be concluded (see Kenning, 2014, p.54). However, we should be careful in interpreting the connection between two brain regions, as the correlation can have multiple causes (see Hubert et al., 2012, p. 4):

(1) brain region A is affected by brain region B.

(2) brain region B is affected by brain region A.

(3) The brain regions A and B influence each other mutually.

(4) Neural activity in a third, unknown region affects the two brain regions A and B.

Hubert et al. (2012) applied the functional connectivity analysis in a FMS study examining confidence building in online contexts. For this purpose, the authors defined two ROIs: the insula and the dorsolateral prefrontal cortex. These two brain regions had been identified in previous studies as neuronal correlates of confidence. The purpose of the functional connectivity analysis was to determine whether the neuronal activities within the insula and the dorsolateral prefrontal cortex interact in a confidence context, or whether the two regions are independently activated. In the end, an interaction effect between the two ROIs (insula and dorsolateral prefrontal cortex) was found (see Hubert et al., 2012, pp. 12-13). As already indicated, only a correlation between the signal strands of two brain regions can be detected by means of the functional connectivity analysis. This form of connectivity analysis is therefore primarily suitable for explorative exploration of activation patterns (see Hubert et al., 2012, p.99). However, to identify a cause and effect relationship between two brain areas, it is necessary to carry out an effective connectivity analysis.

**Effective connectivity analysis**

According to Friston (1994, p. 57), effective connectivity "describes [...] the influence one neural system exerts over another ". The aim of an effective connectivity analysis is therefore the identification of a causal influence that a brain region exerts on another brain region. Kenning (2014, p. 115) emphasizes that the inference about such an influence must always be based on a model. Depending on the neuroeconomic question, the effective connectivity analysis uses various models, also known as mechanistic models. Fleming, Thomas, and Dolan (2010) applied an effective connectivity analysis in their fMRI study on the status quo bias. The status quo bias describes the tendency of people to choose options that do not require an active decision. This non-action is also called a default option. The findings of the effective Connectivity analysis show that the inferior frontal cortex has increased Exerting influence on the subthalamic nucleus if the subject has a difficult Default option rejects or deviates from the status quo (see Fleming et al., 2010, p. 6007).

#### 4.4.3. interim conclusion

fMRI studies based on the idea of functional specialization (see Section 4.4.1.) usually draw on three forms of data analysis. The simplest and most basic form is the individual analysis (see Dimoka, 2012, p. 830). In the context of individual analyzes, sample-specific contrast images are calculated in order to represent separately the activation differences between the experimental conditions for each person (see Huettel et al., 2014, p. 385). It usually makes sense to additionally perform a group analysis. The group analysis draws on the individual probabilities of the individual analysis in order to analyze them on a second level (see Dimoka, 2012, p. 830). In contrast to single and group analysis, which applies to the entire brain, ROI analysis focuses on the study of predefined regions of the brain (see Kenning, 2014, p. The advantage is that the ROI analysis can be used for statistical control of the alpha error probability. The ROI analysis is also suitable for the simplified evaluation of complex experimental designs (see Poldrack, 2007, pp. 67-68). In principle, there is a risk in the context of an ROI analysis that certain brain functions and certain brain regions are wrongly assigned to one another and thus worthless as ROIs (see Huettel et al., 2014, p. 395). If the fMRI study focuses on the study of the interaction of brain regions (see Section 4.4.2.), The functional connectivity analysis or the effective connectivity analysis is applied. The functional connectivity analysis attempts to establish a correlation between the signal strands of two brain regions (see Wohlschläger & Kellermann, 2013, p. 166). These form of the connectivity analysis is primarily suitable for explorative exploration of activation patterns. However, to identify a cause-and-effect relationship between two brain areas, it is necessary to conduct an effective connectivity analysis (see Friston, 1994, p. 57). While functional connectivity is relatively easy to compute, the computation of effective connectivity requires the development of a mechanistic model (see Kenning, 2014, p.90). Table 9 below gives an overview of the various design options in the analysis of fMRI data.

| Aspects | Options | applications / remarks | Example studies |
|---|---|---|---|
| Functional specialization (localization) | individual analysis | - Examination of the entire brain<br>- basic analysis step | Esch et al. (2012) |
| | Group analysis | - Examination of the entire brain<br>- "normalization" of subjects brains necessary<br>- higher generalizability of study results | Dimoka (2010) |
| | ROI-analysis | - Examination of individual brain regions<br>- statistical control for the alpha-error probability<br>- simplified evaluation of complex experimental designs<br>- Problem of faulty localization | Venkatraman et al. (in Druck) |
| Functional integration (connectivity) | Functional connectivity analysis | - simple calculation<br>- makes statements about connections between brain regions<br>- exploratory character | Hubert/Linzmajer/ Riedl/Kenning/ Hubert (2012) |
| | Effective connectivity analysis | - complex calculation<br>- makes statements about cause-and-effect relationships between brain regions | Fleming/ Thomas/Dolan (2010) |

**Table 9:** Design options for analyzing the data

### 4.5. Interpretation of the data

In conclusion, the question arises as to what significance the neuronal activations measured by the fMRI have. There are two ways to interpret fMRI data: The first approach is described by Henson (2006, p. 64) as (1) "forward inference," the second approach by Poldrack (2006, p. 59) referred to as (2) "reverse inference". Both interpretations are described and discussed below.

#### 4.5.1. Forward Inference

In this approach, researchers measure neuronal activity while the subjects undergo a specific cognitive manipulation. Leave after Based on the cognitive task, they speculate as to which specific brain function the respective activated region is responsible for Henson (2006, p. 64) describes forward inference as "the use of qualitatively different patterns of activity over the brain to distinguish between competing cognitive theories ". The approach of Forward Inference is therefore mainly used to review competing theories (see the comments on the aim of the theory review in Section 4.1.1.). In this interpretive approach, the competing theories are regarded as a known quantity, whereas the function of a specific brain region is considered to be an unknown quantity (see Wixted & Mickes, 2013, p.90). In neuroscientific research, for example, the forward inference was added used the single-process theory and the competing dual-process theory of Reminder to test using the fMRI (see Henson, 2006, p. The single-process Theory essentially assumes that memory is a unified psychic process. In contrast, the dual-process theory is based on the assumption that two separate psychic processes interact when remembering (see Kenning, 2014, p. fMRI experiments to validate the two theories are constructed as follows (see Eldridge, Knowlton, Furmanski, Bookheimer & Engel, 2000, Henson, Rugg, Shallice, Josephs & Dolan, 1999): Subjects are first asked to "old" objects, which they have seen a few minutes earlier on a list, to distinguish from "new", unknown to them objects. Afterwards the subjects are asked to indicate for each remembered ("old") object whether they have consciously recognized this or whether they only seemed familiar. The findings of fMRI studies based on this experimental setup show that the actual recall is accompanied by an increased activation of the hippocampus. When identifying trusted objects, however, there is no increased activity of this brain region. Thus, as part of the reminder process two different neural activation patterns are detected. This, in turn, supports the assumption of the dual-process theory that remembrance consists of two components: conscious recognition and the feeling of familiarity (see Henson, 2006, pp. 64-65). The theory-dependent nature of forward inference could prove problematic. For example, it must always be considered that not just one, but both theories of verification do not withstand. Alternatively, a third theory could provide more correct statements about neural activation differences meet. Related to the example explained above it would be So it is conceivable that in addition to the single-process theory and the competing dual Process theory even a third theory exists.

### 4.5.2. Reverse inference

A widely used interpretive approach in consumer neuroscience fMRI studies is reverse inference. According to Poldrack (2006, p. 59), the following reasoning logic is hidden behind the reverse inference: "[I] f cognitive process X is engaged, then brain area Z is active". Thus, the interpretation of the neural activations is not based on the cognitive manipulations carried out in the fMRI experiment (see the comments on forward inference in Section 4.5.1.). Instead, scientists rely on previously published study results to conclude, based on a measured neural activity on the existence of a particular mental process. This is a "backward conclusion", as neuronal activity is linked to a specific brain function. The problem of reverse inference generally concerns the question to what extent psychic processes can be deduced from fMRI data (see Plassmann et al., In press, page 13). Thus, in this context, it should be taken into account that concepts of consumer behavior research

• such as the motivational or attitude construct

• can not necessarily be assigned to specific brain regions.

Kenning (2014, pp. 119-120) further states that the importance of each neural activity is formulated by economists and psychologists in a language that is unsuitable for this purpose. Whether a reverse inference is justified depends on the extent to which a particular neuronal activation and a particular psychological concept are in agreement.

Hedgcock et al. (2012) critically point to another reverse inference problem in their fMRI study of consumer self-monitoring. The authors point out that different brain functions can theoretically trigger the same neuronal activation (Hedgcock et al., 2012, pp. 491-492). As a result, misinterpretation could occur when inferring a specific brain function from neural activity.

### 4.5.3. Interim conclusion

From sections 4.5.1. and 4.5.2. it became apparent that the data interpretation. On the one hand, based on the principle of forward inference, on the other hand, based on the principle of reverse inference. In the case of forward inference, researchers base their cognitive manipulation on assumptions about which specific brain function the respective activated region is responsible for (see Poldrack, 2006, p. 74). According to Henson (2006, p. 64), forward inference is mainly used to review competing theories. Widely used is the reverse inference. In this interpretation approach, a neuronal activity is used to establish a specific brain function. This approach is problematic for two reasons: On the one hand, concepts of consumer behavior research are possible not necessarily assign to specific brain regions (see Plassmann et al., in press, page 13). On the other hand, it is conceivable that different brain functions trigger the same neuronal activation (see Hedgcock et al., 2012, pp. 491-492). Against this background, reverse inference can lead to misinterpretations.

| Aspects | Options | applications / remarks | Example of studies |
|---|---|---|---|
| Interpretation | Forward Inference | - conclude from an experimental manipulation to a specific brain function<br>- to review competing theories<br>- theory dependence | El-dridge/Knowlton/ Furmanski/ Book-heimer/Engel (2000) |
| | Reverse Inference | - from a neural activity to a specific brain function<br>- Misinterpretation possible | Hedgcock/Vohs/ Rao (2012) |

# 5. Conclusion

The fifth chapter summarizes the course and the most important results of the present work. In addition, implications for research and future prospects are shown.

## 5.1. Summary

The growing importance of the young research field Consumer Neuroscience goes hand in hand with the demand that marketing scientists and consumer behavioral researchers deal intensively with the multitude of neuroscientific theories, fields of application and methods (see Plassmann et al., 2012, p. 31, Poldrack, 2012, p 1216-1217). In order to be able to analyze questions of consumer behavior research from a neuroscientific perspective, knowledge about the functioning and application of the fMRI is extremely valuable (Achrol & Kotler, 2012, p.432). However, methodological problems in connection with the fMRI in the marketing research literature have so far been insufficiently discussed (see Table 1 in Section 1.1.). Against this background, the main aim of the present work was to identify and assess options that could be considered in the development of an empirical investigation using the fMRI in consumer behavior research. To narrow down this topic, first the theoretical fundamentals of consumer behavior were outlined. The focus was on the presentation of the unobservable mental processes of consumer behavior. This became the Basis created for the understanding of the young research discipline Consumer Neuroscience, which uses neuroscience findings to examine the psychic processes inside the consumer. The direct comparison of neuroscientific measurement methods further clarified which procedures are suitable for the research projects of consumer neuroscience. Based on this, the basics, strengths and weaknesses of the fMRI method, which is regarded as the so-called "gold standard" (Cui et al., 2011, p. 2808), have been outlined for the research of the human brain. This was followed by the presentation of the following process scheme, which sheds light on design-relevant aspects of empirical investigations using the fMRI: (1) Formulation of the neuroeconomic question; (2) design of experimental design; (3) selection of subjects and data collection; (4) analysis of the data; (5) Interpretation of the data. The listed process steps - with the exception of the data collection - were intensively examined in the main part of this work. The focus here was on the different design tasks that occur within the process steps. In this context, it was primarily of interest to what extent the different design options of empirical fMRI examinations are used in consumer behavior research and in neuroscience. To clarify this question were Examination designs of current fMRI studies analyzed in 2010-2015 senior marketing journals, prestigious journals from contiguous business disciplines and in neuroscientific journals with a high impact factor had been published. In addition, theoretical conceptual work on methodological aspects of the fMRI was included in the literature review. The findings gained in the course of the literature research on the various design options of empirical investigations using the fMRI are summarized below: Firstly, it can be stated that the questionnaire established at the beginning of an fMRI study essentially determines the analysis of the data collected. If localization of activated brain regions is the primary goal of a study, then individual, group, and ROI analyzes are suitable to answer the research question. In contrast, fMRI studies exploring the interconnectedness of brain regions call for more data analysis such as functional and effective connectivity analysis (Friston, 1994, p. 58). Ü Secondly, when designing the experimental design, one should consider that event-related design can answer a wider range of questions than block design. For example. The event-related design allows conclusions to be drawn regarding the time course of neuronal activity, the functional linkage between different brain regions, and long-lasting activations, the stimuli can be arranged more flexibly in the event-related design.

A disadvantage in this context is that the increase in flexibility makes data analysis extremely complex (see Huettel, 2012, p. 1153). Third, it was found that in the subject selection the age and gender any study participants play an important role. After all, age-specific and gender-specific effects can lead to a distortion of the fMRI results. In addition, the size of the sample determines the quality of the fMRT study results: By using large-scale samples in fMRI experiments, one is sufficient test strength is ensured (see Button et al., 2013, p. 365; Guo et al. 2014, p. 172). Fourth, the concept of functional integration, which recognizes the interconnectedness of the human brain, better reflects the actual organizational structure of the brain than functional specialization (Smith, S.M., 2012, p. 1257). Against this background, fMRI studies in the field of consumer neuroscience will increasingly make use of further data analyzes that take this into account. For the investigation of the interaction between brain regions, above all the effective connectivity analysis is suitable (cf. Friston, 1994, p. 57).

Fifthly, the widespread interpretive approach of reverse inference should only be used under certain conditions in fMRI studies. For it is not always possible to open up psychic processes from fMRI data

### 5.2. Implications for research

Decisive quality criteria for fMRI testing in the field of consumer neuroscience are external validity and construct validity. In the effort to achieve an optimal research design, these two criteria should be considered equally: validity depends on the generalizability of test results on real consumer behavior (see Jiménez-Buedo & Miller, 2010, p.127).

The consideration of fMRT studies in consumer neuroscience, published in the period 2010-2015 in A + and A journals, proves that even the most recent studies have very small sample sizes (see Table 7 in Section 4.3.3.). This endangers the external validity of an empirical study using the fMRI and thus the generalizability of the study results. Nonetheless, using a sufficiently large sample size is often difficult to achieve for cost reasons. A promising way out could be to intensify collaboration with other disciplines and thus gain access to large groups of volunteers. Such a procedure also favors Professor Bernd Weber, Center for Economics and Neuroscience Bonn: "Large, mostly from the health sector cohorts are currently being studied together with economic and neuroscientists with regard to economic behavior" (Weber, 2011, p. 21).

One approach to improving construct validity is the multi-method Approach (see also the discussion on convergent validation in Section 4.2.5.). The aim of the multi-method approach is to examine whether the fMRI method is suitable for adequately operationalizing a particular construct. In a concrete fMRI study, for example, in addition to the fMRI, the survey and the observation could be used as additional measurement methods to validate the fMRI results (see Reimann, Schilke, Weber, Neuhaus & Zaichkowsky, 2011, p. 392).

### 5.3. future Outlook

As already detailed in the present work, research into the consumer's brain and its functioning requires competences and methods from various disciplines. In recent years, for example, this has been the result of the establishment of interdisciplinary research institutes, such as the Center for Economics and Neuroscience of the University of Bonn (see Brain Research and Economics, 2011). There is also a doctoral program at the University of Basel Neuro-economics. Furthermore, scientific societies.

The Society for Neuroeconomics, which promotes collaboration between economists and neuroscientists. In addition, some fMRI studies by economists have recently been published in neuroscientific journals (see Plassmann, O'Doherty, Shiv & Rangel 2008). It can be concluded that some fMRI studies with economic background now meet the methodological standards of neuroscientific reporting. The above statements prove that the number of economists with Methodological competencies in experimental neuroscientific research continue to increase. It would be desirable if these scientists could pass on their knowledge to students in the future. It would be conceivable, for example, to offer more events at the faculties of economics at universities, The objective of the practical learning of neuroscientific methods. Also for the future the new establishment of interdisciplinary courses of study is conceivable, which act at the interface of economics and neurosciences. In this way it can be ensured that students of economics learn early to work on neuroeconomic issues. This increase in methodological competence would be particularly beneficial for consumer neuroscience: The still young field of research requires methodically qualified research staff in order to establish itself as an interdisciplinary approach in the long term Future.

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