LINDA COUWENBERG

Context Dependent Valuation

A neuroscientific perspective on consumer decision-making

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Contextgedreven waardeoordelen
Een neurowetenschappelijk perspectief op consumentengedrag

Thesis

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Chapter 1
General Introduction

What makes an anticipated outcome more desirable to people? The answer to this question is of interest to anyone who aims to motivate a particular behavior, such as parents convincing their kids to eat healthy vegetables, or entrepreneurs communicating the value of a new product or service to consumers. While an outcome can be evaluated in absolute terms (for example, the monetary value of the outcome, such as the price of a bottle of wine), we often instead use contextual information as reference points to determine the relative desirability of an outcome (for example, comparing its price to the price of the other bottles of wine on the menu). That is, informative and circumstantial cues can strongly impact our attitudes and behavior toward an outcome, even if this information is not directly related to the outcome itself. Our susceptibility to these reference points can be easily demonstrated. For example, people are likely to be willing to pay more for the same wine if sold in a specialty wine store versus a discount supermarket, presumably because they make use of contextual reference points to determine how much a choice option is worth to them. Since we are often influenced by the context at the moment of choice, our preferences and behaviors can be highly inconsistent. Understanding how contextual information influences our preferences and behaviors would enable us to design choice environments more intentionally. As such, the general question of this thesis is: what is exactly the role of contextual information in choice?

As measuring complex and implicit decision-making processes at the time of choice can be challenging, I argue that neuroscientific methodology could provide valuable insights. The aim of this dissertation is to take an interdisciplinary approach to study how different types of contextual information can increase the desirability of anticipated outcomes and thereby influence common, everyday, (consumer) behaviors. Across three chapters, I examine the general problem of how the brain evaluates contextual information prior to deciding on a subsequent course of action, and address this question by combining behavioral tasks and functional magnetic resonance imaging (fMRI) methodology.

1.1 Measuring Decision-Making Processes

Different academic disciplines have developed models of how attitudes are formed, preferences are constructed, and choices are made. Scholars in psychology, behavioral economics and consumer behavior have built up an extensive literature identifying different factors that drive choice behavior.

Importantly, decades of research has demonstrated that decisions often deviate from classic economic models which assume humans are rational decision-makers. These insights have led to the formation of new, descriptive, models of decision-making. For example, Prospect Theory (Kahneman & Tversky, 1979) predicts different preferences for equivalent outcomes dependent on their framing as either gains or losses, as people are generally more motivated to avoid losses than to achieve gains. Research in this domain typically focuses on revealed preferences (i.e., observations of what people actually choose, or state what they would choose in hypothetical scenarios), coupled with additional variables (such as stated attitudes and intentions, memory, or response times) to advance theories and provide insight into underlying mechanisms.

By using a neuroscientific approach to examine how contextual information is evaluated and integrated into the decision-making process, this dissertation reflects the increased interest in using these methods to study decision-making and related behavior. During the past two decades, this interest has led to the emergence of novel interdisciplinary research disciplines, such as neuroeconomics (e.g., Glimcher et al., 2009; Levallois et al., 2012), social neuroscience (e.g., Lieberman et al., 2007), and consumer neuroscience (e.g., Smidts et al., 2014). Integrating methods and theories from psychology, economics, and neuroscience, scholars in these disciplines aim to contribute to a richer understanding of decision-making by providing more insight into the mechanisms that underlie choice behaviors than is possible using behavioral methods alone. A common limitation of some of these behavioral methods is that they are often confounded by the limited human capacity to consciously identify and accurately report on their mental states through verbal and written reports, or successfully predict their future behavior (e.g., Nisbett and Wilson, 1977). Indeed, asking people to reflect on internal processes leading to choice has been shown to actually bias the outcome and quality of their judgments (Morwitz and Fitzsimons, 2004; Wilson and Schooler, 1991). The strength of neuroscientific methods is that they enable real-time measurement of neural processes both preceding and during decision behavior, and can therefore, in combination with behavioral data, examine more accurately how people make decisions (see, for example, Chan et al., 2019; Eijlers, Smidts & Boksem, 2019). As such, research in these interdisciplinary decision neuroscience areas have combined behavioral tasks (i.e., manipulation of the decision environment to measure effects on choice or other behaviors such as effort and reaction time) with a variety of methods

to 1) measure electrical activities in the brain (i.e., using electroencephalography (EEG), event related potential (ERP), or magnetoencephalography (MEG)), 2) apply transcranial magnetic stimulation (TMS) to influence brain processes, or 3) measure metabolic activities in the brain (i.e., using positron emission tomography (PET) and functional magnetic resonance imaging (fMRI; see also Box 1.1)). Additionally, other psychophysiological methods such as eye-tracking, facial encoding or skin conductance have been applied to gain insight into decision processes. Finally, the effects of genes, hormones, neurotransmitters or drugs are also taken into account.

Box 1.1: functional Magnetic Resonance Imaging (fMRI)

FMRI is a non-invasive method to measure brain activity. Unlike structural MRI, which measures differences between bodily tissues, functional MRI measures changes in the blood oxygenation of the brain over time (blood-oxygenation-level dependent (BOLD) signal) while a subject performs an experimental task in the MRI scanner. From these changes, inferences can be made about the underlying neural activity and how different brain regions may support different (motor, cognitive, or perceptual) processes (Huettel, Song & McCarthy, 2009, p28). FMRI has a relatively high spatial resolution (allowing to scan brain structures with a precision of ~2-3 mm), but it has intermediate temporal resolution, because the BOLD signal is a few seconds slower than the neural event (Huettel, Song & McCarthy, 2009, p220).

While applying neuroscientific methodology has limitations of its own, such as the potentially incorrect labelling of a cognitive process based on observed brain activity (i.e., reverse inference; Poldrack, 2006), in general it can yield substantial insight if interpreted with caution and carefully integrated with existing theory and additional measures (Plassman et al., 2015).

1.2 Consumer Neuroscience

The specific subfield of consumer neuroscience applies neuroscientific insights and techniques to address consumer behavior and marketing problems in order to inform our knowledge about both consumer decision-making processes itself, as well as how context can affect those processes (e.g., Smidts et al., 2014). This domain draws heavily on the related interdisciplinary research areas, in particular neuroeconomics and social neuroscience. Neuroeconomics research, including work on valuation (e.g., Hsu et al. 2005), intertemporal choice (e.g., Kable and Glimcher, 2007), trust and fairness (e.g., Sanfey et al., 2003), self-control (e.g., Hare et al., 2009), and framing (e.g., De Martino et al., 2006), aims to elucidate the mechanisms of decision-making, with a particular focus on models and variables often considered by the field of economics (e.g., reward magnitude, probability, and temporal delay). Building on these insights, consumer neuroscience research focuses on typical marketing questions related to pricing and products (e.g., Knutson et al. 2007; Plassmann et al. 2008), branding (e.g., Chan, Boksem & Smidts, 2018; Chen, Nelson & Hsu, 2015; McClure et al. 2004; Plassmann et al. 2012), advertising and persuasion (e.g., Chan et al., 2019; Doré et al., 2019; Klucharev et al., 2008; Stallen et al., 2010), and other classic consumer research topics such as attraction effects in product choice (Hedgcock and Rao, 2009).

Plassmann et al. (2015) describe five ways in which neuroscientific tools can advance current knowledge of consumer behavior and decision-making processes. First, "neuroimaging tools can help validate, refine, or extend existing marketing theories by providing insights into the underlying mechanism" (Plassmann et al., 2015, p428). Second, "neuroscience techniques can provide information about implicit processes that are typically difficult to access using other approaches" (Plassmann et al., 2015, p428). For example, some responses may be susceptible to self-deception and social desirability, and in some situations the decision-maker may even be unaware of or unable to accurately articulate why he or she engages in a specific behavior. Third, "neuroimaging can demonstrate dissociations between psychological processes" (Plassmann et al., 2015, p428). For instance, fMRI can be used to assess whether different types of decisions engage similar or distinct neural processes, which is indicative of whether these decisions recruit similar or distinct psychological processes. Fourth, "neuroscientific methods can be leveraged to better understand individual differences and thereby explain the sources of heterogeneity in consumer behavior"

(Plassmann et al., 2015, p429). Specifically, individual differences could reflect predictable interactions between genetic markers that code for brain function (e.g., genes that shape our dopamine system), hormone and neurotransmitter levels that fluctuate with disease and state variation (e.g., sleep deprivation), and environmental variables (e.g., stressors or life events; see Yoon et al., 2012 and Venkatraman et al., 2012). Lastly, "incorporating neural measures into decision-making models can improve predictions of marketing-relevant behavior" (Plassmann et al., 2015, p429). One of the first studies testing this hypothesis showed that pre-decisional neural activation predicted subsequent purchasing decisions (Knutson et al., 2007). Moreover, this paper found that adding neural measures to self-reported preferences led to significantly better predictions. This finding has since been replicated in numerous studies identifying neural signals predictive of the actual choices individuals make (e.g., Falk et al. 2011; Tusche, Bode, and Haynes, 2010, see also Bartra, McGuire, and Kable (2013) for a meta-analysis on regions in the brain's valuation network encoding subjective value). Interestingly, neural activity in a small sample of subjects has been shown to be predictive of population-wide commercial success of products (Barnett and Cerf, 2017; Berns & Moore, 2012; Boksem & Smidts, 2015; Chan et al., 2018; Falk, Berkman, & Lieberman, 2012; Venkatraman et al., 2015), market-level microlending (Genevsky & Knutson, 2015), as well as crowd-funding outcomes (Genevsky, Yoon & Knutson, 2017; see Knutson & Genevsky, 2018 for a review on neuroforecasting studies).

In summary, there is a growing body of knowledge as to how (consumer) decision-making is shaped by neural and physiological factors, contributing to the broader goal of understanding the factors and processes that drive our behavior.

1.3 Aims and Outline of Dissertation

In this dissertation, I explore how combining behavioral and fMRI methodology can advance our understanding of three different phenomena in common, everyday, consumer behavior that have been well-established both in the lab and in the field. I aim to address open questions regarding the mechanisms that underlie these phenomena, with the goal of complementing existing research by taking an interdisciplinary perspective and applying neuroimaging methodology.

In three empirical fMRI studies, I particularly focus on how the brain processes (both subtle and more explicit) contextual cues that have previously been identified as impacting the desirability of an anticipated outcome, and how these brain processes are subsequently related to observed behavior. In the next chapters of this dissertation, I first discuss the motivational processes underlying goal-directed behavior (Chapter 2), then outline the mechanisms of variety seeking in a consumer choice context (Chapter 3), and lastly, address the question of how different elements in commercials are processed and thereby drive interest in the promoted product (Chapter 4). In each of these chapters, I connect theory and insights from the consumer behavior domain with methodology and insights from the (decision) neuroscience domain.

In **Chapter 2**, I focus on a construct that is very fundamental to human behavior: motivation. More specifically, I examine fluctuations in motivation across the course of goal pursuit, and how associated progress cues are monitored in the brain. Classic and modern behavioral research on goal pursuit has repeatedly demonstrated that as humans and other animals approach a desired end state, their efforts toward reaching that end state increase. This pattern has been termed 'goal gradient motivation'. Using fMRI, we address the question of how goal proximity is encoded in the human brain, in order to better understand how reaching this end state becomes more desirable over time. In this experiment, participants worked through a series of sequential actions towards an anticipated reward, during which they could monitor their progress relative to this reward. We used an MRI compatible handgrip to measure effort (i.e., a combination of force and reaction time) to infer participants' motivational state. Our findings suggest that reward proximity is continuously monitored in the brain's reward and salience networks, and, importantly, is used to regulate subsequent effort production.

In **Chapter 3**, I present insights into how cues in a consumer choice context can increase or decrease the desirability of choice alternatives. In particular, I examine how one's own history of choices impacts subsequent variety-seeking behavior. Previous behavioral research has shown that when asked to select several options at once, people tend to choose a greater diversity of items than when they are asked to make these selections one at a time. Despite the pervasiveness of daily life situations in which multiple selections are required, and the demonstrated profound consequence of this 'diversification bias' on choice outcomes, little is known about the mechanisms that drive this phenomenon. We investigated this question by scanning participants using

fMRI while they made multiple selections from a menu of different options. Our results show that the current state of their choice portfolio (i.e., the previously selected options) dynamically modulates activity in the neural valuation system in response to the options under evaluation, through both 'satiation' and 'novelty-seeking' processes. This research has been published in Frontiers in Neuroscience (Couwenberg et al., 2020).

In **Chapter 4**, I take a more applied approach by exploring neural responses to different ways of framing the value of a product (i.e., ad appeals) in television commercials, and test if these are related to the effectiveness of the commercial. Prior research indicates that internal processes in response to ad appeals are important mediators of ad effectiveness. In this study, we aim to build upon this extensive body of research by using fMRI to measure the neural processes associated with different executional elements. Comparing a set of different television commercials for the same brand enabled us to investigate the influence of differences in ad appeal, in terms of its functional and experiential elements, on brain responses in a 'neural focus group' and subsequent ad effectiveness in an independent sample of consumers. Findings show that functional and experiential executional elements engage different brain areas, associated with both cognitive and emotional processes, and that the extent to which these particular brain networks are activated and interact, is associated with higher ad effectiveness. This work has been published in the International Journal of Research in Marketing (Couwenberg et al., 2017).

Finally, **Chapter 5** concludes this dissertation with a summary of the key findings, and a discussion of the limitations and future directions for each of the three empirical chapters. I argue that the findings in this dissertation research contribute to the existing literature, and that taking an interdisciplinary research approach facilitates theory development and shapes models of consumer decision-making. I finish with suggestions as to how insights generated by this dissertation can be applied by marketing professionals, user experience designers, and public policy-makers.

1.4 Declaration of Contribution

Chapter 2 is based on work with Maarten Boksem (MB), Alan G. Sanfey (AGS) and Ale Smidts (AS). I (LC), formulated the research question and designed the study, in collaboration with MB, AGS and AS. LC collected the fMRI data. LC

analyzed the data, with input from MB, AGS and AS. LC wrote the manuscript and implemented feedback from MB, AGS and AS.

For Chapter 3, LC formulated the research question and designed the study, in collaboration with MB, AGS and AS. LC collected the fMRI data. LC analyzed the data, with input from MB, AGS and AS. LC wrote the manuscript and implemented feedback from MB, AGS and AS.

For Chapter 4, LC formulated the research question and designed the study, in collaboration with MB, Roeland Dietvorst (RD) and AS. RD and Loek Worm (LW) collected the fMRI data. The stimuli and population data were provided by RD, LW and Willem Verbeke (WV). The expert data was collected by LC, with support from WV. LC analyzed the data, with input from MB and AS. LC wrote the manuscript and implemented feedback from MB and AS.

LC wrote Chapter 1 and Chapter 5, and implemented feedback from MB, AGS and AS.

Chapter 3
Neural Mechanisms of Choice Diversification[1]

[1] This chapter is based on Couwenberg, L. E., Boksem, M. A. S., Sanfey, A. G., & Smidts, A. (2020). Neural Mechanisms of Choice Diversification. *Frontiers in Neuroscience,* 14:502. https://doi.org/10.3389/fnins.2020.00502

3.1 Abstract

When asked to select several options at once, people tend to choose a greater diversity of items than when they are asked to make these selections one at a time. Using functional magnetic resonance imaging, we provide novel insight into the neural mechanisms underlying diversification in portfolio choices. We found that, as participants made multiple selections from a menu of different options, the current state of their choice portfolio (i.e., the previously selected options) dynamically modulates activity in the neural valuation system in response to the options under evaluation. More specifically, we found that activity in the ventral striatum decreases when the option has already been selected ('satiation'), while activity in the ventromedial prefrontal cortex increases when other options have previously been selected ('novelty-seeking'). Our findings reveal two processes that drive diversification in portfolio choices, and suggest that the context of previous selections strongly impacts how the brain evaluates current choice options.

3.2 Introduction

We frequently find ourselves in situations that require us to make multiple simultaneous selections from an often wide array of available options. For instance, we may decide to go to the supermarket on the weekend to buy several tubs of yogurt in anticipation of our weekly consumption. Research has shown that when asked to select several options at once for future use, people tend to choose a greater diversity of items than when they are asked to make these selections one at a time (i.e., choosing one tub of yogurt each day; e.g., Simonson 1990; Read and Loewenstein 1995). This tendency to diversify a choice portfolio typically leads to the selection of alternatives that are not usually purchased (Simonson and Winer 1992), and the selection of relatively more 'virtues' than 'vices' (Read et al. 1999). Interestingly, people are even willing to even forgo preferred options, making suboptimal choices, in order to construct choice portfolios with greater diversity (e.g., Read et al. 2001). For example, when selecting several tubs of yogurt, we may not only select our favorite flavor (i.e., strawberry), but also a less liked option (i.e., banana). This diversification phenomenon in choice behavior has been robustly demonstrated in various domains, such as food or movie selection, and similar patterns have been documented when allocating continuous resources (such as money) across a set of alternatives. For instance, people tend to diversify retirement savings relatively evenly across a set of possible

investment instruments (Benartzi and Thaler 2001), irrespective to some degree of return rates of each.

Despite the pervasiveness of daily life situations in which multiple selections are required, and the demonstrated profound consequence of diversification on choice outcomes, little is known about the mechanisms that drive this process. Insights into the neural mechanisms underlying these decisions are therefore important in advancing our understanding of this ubiquitous phenomenon.

According to the classic utility maximizing framework (e.g., Von Neumann and Morgenstern 1947), a decision-maker first determines the utility of each available option, and then selects that option with the greatest utility. However, as people proceed through a series of choices, the state of their choice portfolio accordingly changes with each additional selection. To explain diversification, we propose that, in response to these changes, the utility of the available options in the choice set is updated dynamically. More specifically, we hypothesize that (1) the utility of an option decreases when it has previously been selected, this making it less likely to be added again, and/or (2) the utility of a non-chosen option increases when alternative options have already been added to the portfolio, which in turn leads to a greater chance of it being selected. Both of these proposed mechanisms could independently drive diversification. However, while the first hypothesis suggests a ('passive') mechanism reflecting diminishing marginal utility ('satiation'; e.g., McAlister 1982), the second hypothesis points to an intrinsic appreciation of change ('novelty-seeking'; e.g., Venkatesan 1973).

Previous research on how the brain computes and represents choice utility has identified several neural areas that appear to carry a domain-general utility, or 'value', signal. These areas, often termed the 'valuation system' (Bartra et al. 2013), include dopamine rich regions such as the ventral striatum (VS) and the (ventro)medial prefontal cortex ((V)MPFC; e.g., Knutson and Cooper 2005; Delgado 2007; Levy and Glimcher 2012). Although previous research using functional magnetic resonance imaging (fMRI) has been primarily concerned with exploring single choices made in isolation, a relevant insight is that value representation in the brain appears to be context-dependent (e.g., Plassmann et al. 2008; Seymour and McClure 2008; De Martino et al. 2009), suggesting that a change in context due to previous selections may affect valuation of currently evaluated items.

Taken together, we hypothesize that as people make multiple selections from a given choice set, the state of one's choice portfolio (i.e., the history of previously selected options) will dynamically modulate activity in the neural valuation system, leading – through either (or both) a 'satiation' and 'novelty-seeking' mechanism – to the commonly observed phenomenon of diversification of choice. We investigated this question, and the proposed mechanisms of interest, by scanning participants using fMRI while they made a series of product choices.

3.3 Materials and Methods

3.3.1 Participants

Forty-five participants completed the study. All provided written informed consent and were financially compensated via either a flat fee (30 Euro) or study credits for completion of the task. In addition, all participants received one or more prizes (see below) in addition to this participation fee. Exclusion criteria included self-reported claustrophobia, neurological or cardiovascular diseases, psychiatric disorders, regular use of marijuana, use of psychotropic drugs, metal parts in the body or any dietary restrictions (as many stimuli in the task were food items). Four participants were excluded due to excessive movement (> 3 mm) during fMRI data acquisition. Data is therefore reported from 41 participants (13 men and 28 women, M = 22.73 years, SD = 3.28, range = 18 to 34 years, all right-handed). The study was approved by the local institution's ethics committee.

3.3.2 Stimuli

We selected 40 product categories, each incorporating five different products, to present as choice sets in the task. The majority of the product categories (i.e., 26 out of 40) consisted of food items (e.g., noodles, soup, or cereal). The remaining categories consisted of a variety of non-food items, such as socks, mugs, or hand soap. Within each category, the products were of the same brand and were priced similarly, but differed in terms of flavor, scent or color (e.g., five different flavors of instant noodles). Participants' liking scores for each of the 200 products was assessed on an 11-point slider scale with decimal accuracy (0 = '*I don't like this product at all*', 10 = *'I really like this product'*) in an online survey before the scanning session. In this survey, the products were presented per category, such that the five products per category were rated on

the same page, ordered randomly. Based on these liking ratings, we ranked the products within each category for each participant individually. We ranked equally liked items (i.e., up to the second decimal) in random order. In order to select the most desirable set of stimuli for each participant, we excluded five product categories in which the most liked product had a liking rating lower than 4 on the 11-point scale. In case we were not able to exclude five product categories using this rule, we excluded categories with the greatest similarity in liking ratings. We used these excluded product categories in the filler trials. The remaining 35 product categories were presented in the trials of interest.

3.3.3 Task

We developed a novel paradigm to study the neural mechanisms underlying diversification in choice behavior, optimized to disentangle the hypothesized 'satiation' and 'novelty-seeking' mechanisms. Participants were informed that they would participate in a study examining reaction time accuracy. Each series of choices in our experiment was preceded by a simple time-estimation task (Boksem et al. 2011), in which participants saw a greyscale visual cue that changed to color after 1000 ms. Participants were instructed to press a response button exactly 1000 ms after this color change. Responses were considered correct when reaction times fell within an allowable time-interval. Participants continued onto a new time-estimation trial if their response did not fall within this time-interval (i.e., either too fast or too slow). After a correct response, participants began the choice part of the task (i.e., the task of interest) in order to select their prize(s). The purpose of this time-estimation task was to both maintain engagement throughout the task, and, importantly, to create a context for making a series of product choices. Participants were instructed that one of the time-estimation trials they played would be randomly drawn at the end of the experiment and that – if they had been successful on that trial – they would receive the prize(s) they had selected after that specific trial.

Upon entering the choice part of the task, participants viewed a screen consisting of a choice set of five products from a specific product category (e.g., five different flavors of instant noodles). One of these five products was highlighted, and participants were instructed to passively evaluate this product for 3000 ms (i.e., they were asked to consider "*Do you want this product?*"). This evaluation screen constituted the time window of interest for the statistical analyses, and its onset was jittered (3000-5000 ms). Participants

were then asked to make their decision to either accept or reject this specific product using a button box (placed in their dominant hand). The task advanced right after the participant made their choice, with a maximum response time of 2500 ms. To stimulate participants to only accept products they really wanted on each specific choice occasion, participants did not know in advance how many total products per choice set they would get to select. That is, every decision to accept could be their final opportunity to select a product from the current category. Participants could reject products an unlimited number of times (e.g., they could choose to wait, at some risk, for their highest preference product to be offered). In each of the 35 choice trials of interest for our analyses, participants could select a total of three prizes. A different choice set (i.e., product category) was used in each of these trials. To ensure that each accept-decision in these trials was consequential, participants could select a total of one, two or four prizes in the remaining 14 filler trials. In these filler trials, each of the five excluded product categories was repeated 2 or 3 times. The filler trials were distributed pseudo-randomly throughout the whole experiment, such that the trials of interest were alternated with filler trials.

Once a product was accepted it appeared in a 'basket', which was always visible below the choice options. The main goal of the study was to investigate the influence of the dynamic state of this 'basket' (i.e., the products it contained during the evaluation phase) on neural responses and subsequent choice. After accepting a product, participants either evaluated another product, or continued with the next time-estimation trial (i.e., when the total number of selections for the current category was reached). If they rejected a product, participants continued to evaluate products, until they accepted one.

The order in which the products were to be evaluated was first based on the product rankings, and then dynamically updated based on the participants' decisions for that specific category. This allowed us to control the number of observations of interest to distinguish between the 'satiation' and 'novelty-seeking' mechanisms, without restricting participants' freedom of choice. That is, within each series of choices, we presented participants with a previously accepted product for a second time in order to test whether choice and neural valuation for this option would decrease (i.e., 'satiation'). Additionally, we exposed participants to a previously rejected product for a second time, in order to test whether choice and neural valuation for a previously non-selected option would increase once different products had

been selected in the meantime (i.e., 'novelty-seeking'). We optimized the sequence of product evaluations to maximize the number of these type of observations, by presenting lower ranked products first (to elicit a 'reject' decision), and then higher ranked products (to elicit an 'accept' decision). A previously accepted product was then presented again (now with this same product in the 'basket'), and a previously rejected product was only presented again once there was another accepted product in the 'basket'. As this product presentation sequence was dependent on the participants' decisions in the task, the number of repeated exposures to accepted or reject products could differ by product category and participant (see *FMRI Data Analysis* section for details). Participants were free to either make the same choice (accept (reject) a previously accepted (rejected) product again) or change their mind (accept (reject) a previously rejected (accepted) product). In the filler trials, the sequence in which the products were presented followed the rank order, starting with the highest ranked product. See Figure 3.1 for a pictorial overview of the choice task.

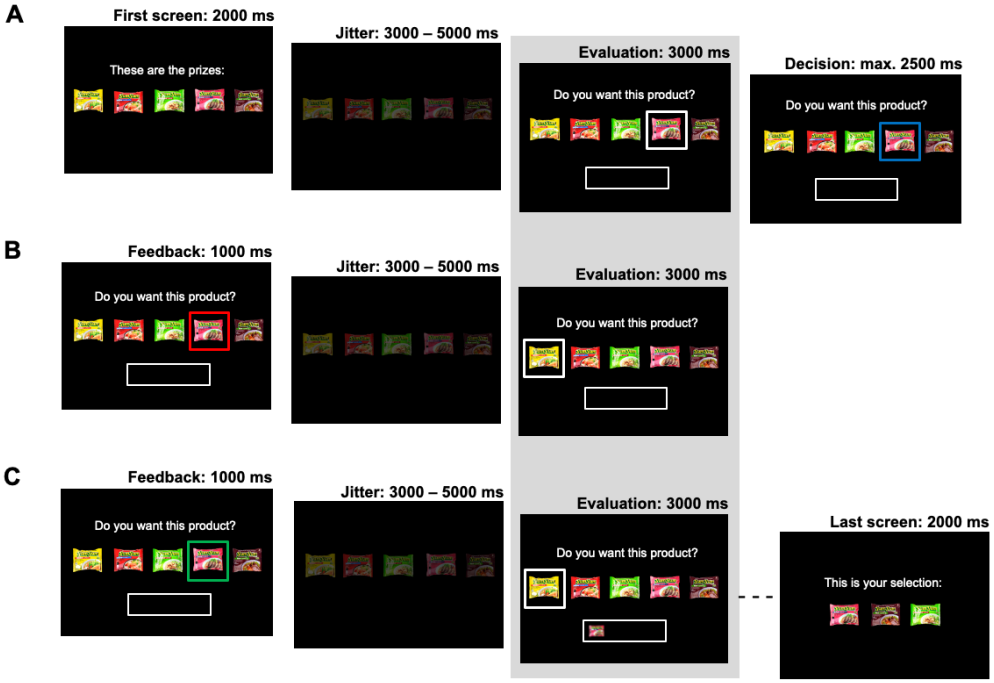

Figure 3.1. Task Design. The structure of the choice task is presented. Each picture represents a screen in the experiment. The evaluation screen (indicated by the shaded area) constituted the screen of interest for the analyses and its onset was jittered (3000 – 5000 ms). A) Each choice set consisted of 5 products. One product was offered at the time (highlighted with a white box). This focal product was evaluated (cued by a blue box), and then accepted or rejected. B) When the product was rejected (red box), another product was evaluated. C) When a product was accepted (green box), it then appeared in the basket. Products were evaluated until three products were selected. After the last screen, a new time-estimation trial started.

3.3.4 Procedure

At least three days before the fMRI scanning session, participants completed an online survey in which we assessed their liking for each of the products presented in our task. Upon arrival in the fMRI lab, participants performed two practice sessions. In the first session, participants practiced the time-estimation task. In this practice, which consisted of 20 trials, we used a minimum and a maximum response time to determine an initial allowable response time-window (i.e., 700 – 1300 ms). If participants responded within this time-window, this interval was shortened by 50 ms; if they responded either too quickly or too slowly, the interval was lengthened by 50 ms. The resulting interval after the last practice trial was used as the time-window for the time-estimation task in the experiment, thus individually calibrated for each participant. This time-window was covertly adjusted throughout the experiment in order to ensure a sufficient number of hits (and thus choice trials). If participants responded within the allowable time-window, the interval was shortened by 10 ms; if they responded either too quickly or too slowly, the interval was lengthened by 90 ms. So, although the proportion of hits (+/- 90%) and misses (+/- 10%) was controlled, the feedback was contingent upon participants' actual performance.

In the second practice session, participants became familiar with the choice task. After these practice sessions, participants entered the scanner and practiced with the button box. The experiment, which was programmed and presented in Presentation software (Version 16.3, www.neurobs.com), was one continuous run of approximately 45 minutes while fMRI data was being collected. After the experimental task, we collected the anatomical scan. Finally, participants were thanked and paid. For the bonus payment we only selected from hit trials, although participants were made to believe that both hit and miss trials in the time-estimation task could be randomly drawn, as the number of hits and misses was controlled. Each participant was therefore awarded up to four of their selected product(s) in addition to the participation fee.

3.3.5 FMRI Data Acquisition

Imaging was performed using a 3-Tesla head-dedicated MRI system (Siemens Magnetom Skyra). Functional MRI images were acquired using a 32-channel head coil, with a standard multi-echo imaging pulse T2*-weighted sequence

(field of view (FOV): 224 mm; 64 × 64 matrix; repetition time (TR): 2250 ms; echo times (TE): 9.4 ms, 21.2 ms, 33 ms, 45 ms, 56 ms; flip angle: 90°, 0.5 mm slice gap). Using a multi-echo sequence provides a better signal-to-noise ratio for brain areas susceptible to drop-out, while allowing for scanning of the whole brain (Poser et al. 2006). Thirty-five ascending slices were acquired (thickness: 3.0 mm; voxel size: 3.5 × 3.5 × 3.0 mm) from the whole brain. High-resolution anatomical T1-weighted image (MPRAGE; 192 slices; TR: 2300 ms; voxel size: 1 × 1 × 1 mm) was acquired for anatomical localization. Participants' heads were lightly restrained with tape loosely placed between their head and the coil within the scanner in order to limit movement during image acquisition.

3.3.6 FMRI Data Analysis

Analyses on the brain data were performed using SPM12 (Statistical Parametric Mapping; Wellcome Department, London, UK). Prior to preprocessing, we combined and realigned the five read-outs acquired via the multi-echo sequence by using standard procedures described by Poser et al. (2006). Preprocessing consisted of realignment, slice-time correction to the middle slice, segmentation of the functional and anatomical image, co-registration of the functional images to the anatomical images, and normalization to the Montreal Neurological Institute (MNI) template using the segmentation parameters. Functional images were then smoothed with a Gaussian kernel of 8 mm full-width at half maximum (FWHM). The first 30 volumes, acquired prior to task initiation, were used to estimate the weighted echo time per voxel for optimal echo combination (Poser et al. 2006) including allowing T1 equilibration effects, and discarded from the analysis. Motion parameters were stored and used as nuisance variables in all generalized linear model (GLM) analyses. The task consisted of a single run of approximately 45 minutes; a standard high-pass filter (cut-off 128 s) was used in the analyses to account for possible slow-frequency drifts.

For the statistical analyses of the brain data, we first ran first-level GLMs to identify the brain regions related to the choice to accept a product (the 'valuation network'). The model consisted of two regressors of interest (1. 'accept', 2. 'reject') that were time-locked to the evaluation screens of the choice part of the task, with 'accept' and 'reject' referring to the subsequent choice outcome. We performed a t-test at the group-level, contrasting the two regressors to find the unique activations related to the decision to 'accept' (vs.

'reject'). All reported main results exceed the statistical threshold of $p < .05$ FWE corrected on the cluster-level.

Next, we assessed how the dynamic state of the choice portfolio modulated activity in the brain regions associated with the decision to accept a product. To this end, we constructed regions-of-interest (ROIs) within the most significant brain regions (3 mm radius spheres around the most significant peak voxels) from the 'accept' vs. 'reject' contrast. We extracted parameter estimates from the selected ROIs with MarsBaR (Brett et al. 2002), using first-level GLMs with a separate regressor for each observation, time-locked to the evaluation screen. To test our 'satiation' hypothesis, we only selected choice options that were accepted the first time they were evaluated ('satiation T1'), and also evaluated a second time ('satiation T2'). This subset of observations included a total of 1455 pairwise comparisons across all participants, with at least 1 pairwise comparison in each of the 35 choice portfolios per participant (median number of pairwise comparisons per participant = 35; minimum = 35; maximum = 39). To test our 'novelty-seeking' hypothesis, we selected a different subset of choice options that were rejected the first time they were evaluated (when the 'basket' was empty; 'novelty-seeking T1'), and then evaluated a second time once other choice options were selected in the meantime ('novelty-seeking T2'). This subset of observations included a total of 856 pairwise comparisons across all participants, with at least 1 pairwise comparison in on average 47.6% of the 35 choice portfolios per participant (median number of pairwise comparisons per participant = 21; minimum = 7; maximum = 36). For both subsets, we tested for pairwise differences in signal change using repeated measures ANOVAs in R software (www.R-project.org), with the effect of time (T1, T2) nested within participants.

3.4 Results

3.4.1 Behavioral Data

The data show that participants indeed diversified their choice portfolio in the majority of the product categories. Overall, of the total of 1435 choice portfolios of three products each, 47.2% consisted of 2 unique items, and 33.2% of 3 unique items. A minority of the choice portfolios (19.6%) consisted of 3 of the same items, and thus were not diversified. In addition, each

individual participant diversified a substantial number of their 35 choice portfolios (median = 30; min = 14; max = 35).

To test if participants diversified because of 'satiation' or 'novelty-seeking', we ran non-parametric Wilcoxon signed-rank tests to compare probabilities of selecting an item, dependent on particular states of the basket. To make sure that we compared products of similar a priori liking, we created bins of items of homogeneous relative preference based on rank score. We selected Rank 1 and Rank 2 items for our 'satiation' test because these occurred most often in the task to maximize the number of "satiation" observations. We selected Rank 3 and Rank 4 for novelty seeking because these occurred most often in the task to maximize the number of 'novelty' observations. We omitted the least liked items (Rank 5) items because the limited number of observations. To test our 'satiation' hypothesis we ran a Wilcoxon signed-rank test, comparing the probability of accepting a product given that it is not in the basket with the probability of accepting a product given that it is in the basket, indicating a significant decrease in probability ($P_{T1\text{-}Accept}$ = .863, $P_{T2\text{-}Accept}$ = .552, Z = -5.073, p = .000). To test our 'novelty-seeking' hypothesis we ran another Wilcoxon signed-rank test, comparing the probability of accepting a product given that the basket is empty with the probability of accepting a product given that other items (but not the current item) are in the basket, showing a significant increase in probability ($P_{T1\text{-}Accept}$ = .331, $P_{T2\text{-}Accept}$ = .453, Z = -4.062, p = .000). These results indicate that as people make multiple selections from a given choice set, the state of one's choice portfolio (i.e., the history of previously selected options) leads – through both 'satiation' and 'novelty-seeking'– to diversification of choice.

In addition, of the subset of 1455 pairwise observations selected to test the 'satiation' hypothesis on the neural data (i.e., choice options that were accepted the first time they were evaluated, and also evaluated a second time), the item was rejected at T2 in 40.7% of the cases (reject rate per participant: median = 34%, min = 0%; max = 91%). In 67.2% of those cases, the rejected item was the most preferred item (i.e., the item with the *highest* a priori liking score). Of the subset of 856 pairwise observations selected to test our 'novelty-seeking' hypothesis on the neural data (i.e., choice options that were rejected the first time they were evaluated (when the 'basket' was empty), and then evaluated a second time once other choice options were selected in the meantime), the item was accepted at T2 in 19.6% of the cases (accept rate per participant: median = 14.2%, min = 0%; max = 47%). In 52.4% of those cases,

this was the third item added to the 'basket', and the majority of those selections included the third ranked item (75.6%).

We further hypothesized that if people diversified, they would be willing to accept products with lower liking ratings than their most preferred product. We ran a linear mixed model (with random intercepts for individuals) to test if liking ratings of the most liked product and the selected products in a given product category are significantly different. The results show that this difference was highly significant ($M_{\Delta \text{ Highest Liking – Mean Liking (Accepted)}} = .737$; $t(40) = 13.82$, $p = .000$). Moreover, we found that the higher the variety (number of unique items) across choice portfolios, the higher this difference in liking (Pearson's $r = .565$, $p = .000$).

In summary, these findings suggest that utility of options in the choice set is indeed modulated by the dynamic state of the choice portfolio, and they provide clear behavioral indications of both 'satiation' and 'novelty-seeking' processes.

3.4.2 FMRI Data

3.4.2.1 Neural correlates of choice

We found expected brain activation patterns in response to evaluated choice options that were subsequently accepted, as compared to those that were evaluated and rejected. Areas of increased activations for accepted as opposed to rejected options included a cluster spanning the VS (bilateral nucleus accumbens), the MPFC, and the VMPFC (see Figure 3.2). Other regions identified by this contrast were the middle temporal gyrus, inferior frontal gyrus, middle occipital gyrus, midbrain, and precuneus. Although we were primarily interested in the neural activity related to the decision to accept ('positive valuation'), we also analyzed the opposite contrast ('reject' > 'accept'). When participants subsequently rejected the choice option under evaluation, we found increased activity in the supramarginal gyrus extending into the putamen, superior temporal gyrus, middle and inferior frontal gyrus, angular gyrus, calcarine and cerebellum. See Table 3.1 for a detailed overview of our findings.

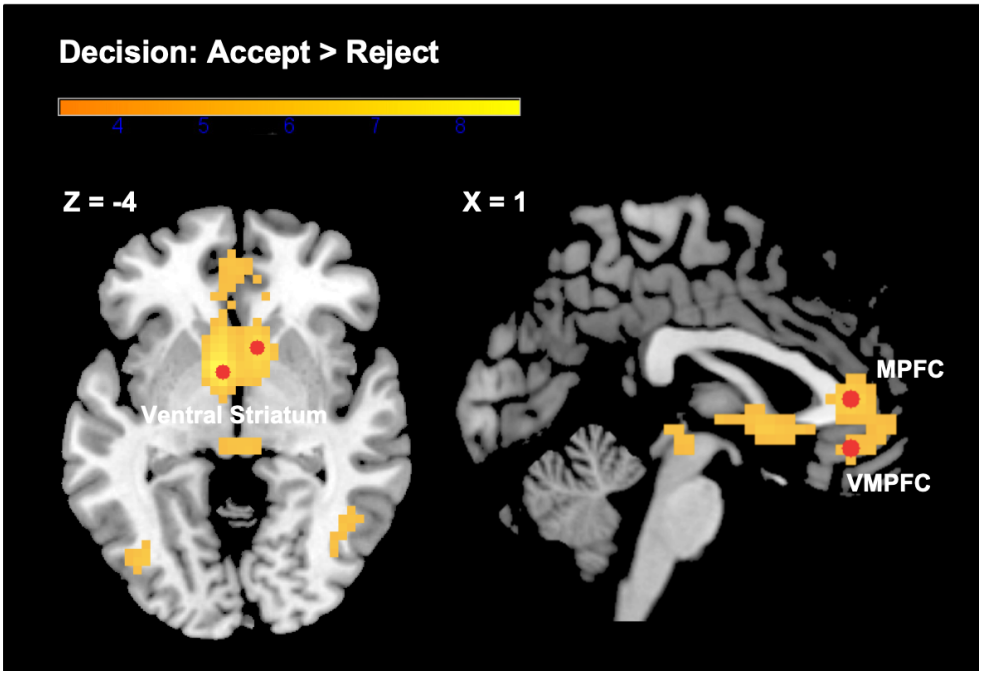

Figure 3.2. Brain activations in the VS, MPFC and VMPFC from the contrast 'subsequent decision: accept > reject'. Color bar represents t-statistics. Selected ROIs (3 mm radius spheres around the most significant peak voxels) are depicted in red. See Table 3.1 for more details not shown here.

Table 3.1. Brain activations for subsequent decision (accept, reject)

Anatomy	Hemisphere	MNI Coordinates			Cluster size	Z
	L/R	x	y	z	[k voxels]	
A) Accept > Reject						
VS / MPFC / VMPFC					435	
VS (NAcc)	L	-6	4	-4		6.47
VS (NAcc)	R	8	14	-4		5.25
MPFC	R	1	35	7		4.65
VMPFC	R	1	35	-10		3.72
Middle Temporal Gyrus	R	43	-70	7	137	4.81
Middle Occipital Gyrus	L	-38	-74	4	75	4.74
B) Reject > Accept						
Supramarginal Gyrus / Putamen	L	-52	-24	21	1386	6.33
Superior Temporal Gyrus	R	68	-21	4	212	4.88
Middle Frontal Gyrus	R	36	42	32	457	4.74
Angular Gyrus	R	57	-60	28	95	4.66
Middle Frontal Gyrus	L	-34	38	28	89	3.85

Note: A) Brain activations for subsequent decision (accept > reject). B) Brain activations for subsequent decision (reject > accept). All reported activations exceeded the threshold of $p < .05$ FWE corrected on the cluster-level. Z-values for each peak are given. Abbreviations: L = left; R = right; VS = ventral striatum; NAcc = nucleus accumbens; MPFC = medial prefrontal cortex; VMPFC = ventromedial prefrontal cortex. N = 41.

3.4.2.2 Choice portfolio effects

In order to test how valuation of options in the choice set is modulated by the current state of the choice portfolio, and to further tease apart the potential proposed 'satiation' and 'novelty-seeking' mechanisms, we focused subsequent analyses on the cluster of neural activity most significantly correlated with the decision to accept. This cluster spanned regions typically related to positive valuation in previous studies (the VS, the MPFC and the VMPFC). We constructed three ROIs around the most significant peak voxels within this cluster: in the VS (bilateral; x: -6, y: 4, z: -4 and x: 8, y: 14, z: -4 (left and right averaged)), the MPFC (x: 1, y: 35, z: 7) and the VMPFC (x: 1, y: 35, z: -10), and extracted parameter estimates for the evaluation phase of each trial.

First, we tested the 'satiation' hypothesis, which posits that activity in the valuation network decreases when the evaluated option has previously been selected. We compared signal change in response to choice options evaluated for the first time (and subsequently accepted; T1), with the same option evaluated a subsequent time when this item was already in the 'basket' (T2). Repeated measures ANOVAs reveal that activity in the VS decreases significantly between T1 and T2 ($M_{\Delta T2\text{-}T1}$ = -.022; $F(1,40) = 5.188$, $p = .028$). This difference between T1 and T2 showed similar patterns in the MPFC and VMPFC, though did not reach significance in these other areas ($F(1,40) = .618$, $p = .436$; $F(1,40) = .193$, $p = .663$, respectively), see Figure 3.3 for details. These results show that valuation, particularly in the VS, for a particular choice option decreases when it has previously been selected.

It should be noted that, as we defined our ROIs based on the 'accept' > 'reject' contrast, comparing 'accept' trials at T1 with 'accept' and 'reject' trials at T2 within these ROIs could potentially inflate the results. To check this, we ran a linear mixed model (with random intercepts for individuals) to test if the observed decrease in signal change in the VS is significantly different for items that were accepted or rejected at T2. The results show that this was not the case ($t(1453) = -.861$, $p = .38$). In addition, we analyzed whether the differences could be observed in a specific subset of pairwise comparisons of the same choice option with the same choice outcome (i.e., T1: 'accept'; T2: 'accept'). The results indeed show a decrease in activation in the VS, also for items that were accepted again ($M_{\Delta T2\text{-}T1}$ = -.014), even though this difference did not reach statistical significance ($F(1,40) = 1.216$; $p = 0.277$). It should be noted that this is a highly conservative test, as we do not necessarily hypothesize a

difference within this particular subset of observations (we actually hypothesize 'reject' decisions at T2).

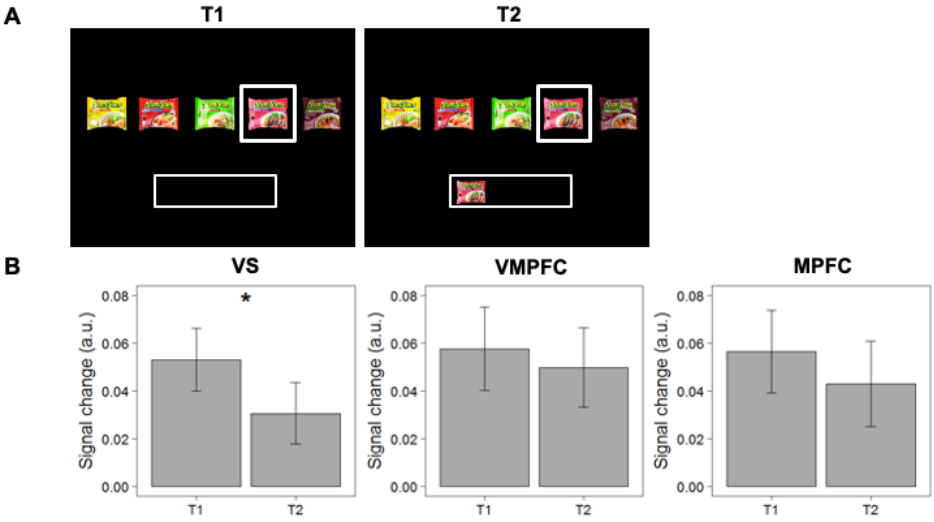

Figure 3.3. Test of the 'satiation' hypothesis. A) Example of a pairwise comparison of the first time an option was evaluated (T1) and the second time the same option was evaluated when this option was already in the 'basket' (T2). B) Differences in signal change between T1 and T2 in the VS, VMPFC and MPFC. Error bars represent standard errors of the mean. The difference in signal change between T1 and T2 is only significant in the VS ($F(1,40) = 5.188$, $p = .028$).

Second, we tested the 'novelty-seeking' hypothesis, which suggests that activity in the valuation network for a non-selected option increases when alternative options have been already chosen. We compared signal change in response to choice options when evaluated for the first time with an empty 'basket' (and subsequently rejected; T1), with the same choice option when evaluated a second time when other choice options were now in the 'basket' (T2). We find that activity in the VMPFC increases significantly between T1 and T2 ($M_{\Delta T2\text{-}T1} = .055$; $F(1,40) = 5.281$, $p = .027$). The difference between T1 and T2 was not significant in the VS ($F(1,40) = .157$, $p = .694$), nor in the MPFC ($F(1,40) = .007$, $p = .933$). See Figure 3.4 for details.

To account for the possibility of inflated results, we ran another linear mixed model (with random intercepts for individuals) to test if the observed decrease in signal change in the VMPFC is significantly different for items that were accepted or rejected at T2. The results show that this increase in signal change in the VMPFC is not significantly different for items that were accepted versus rejected at T2 ($t(816.84) = .138$, $p = .891$). Moreover, we analyzed whether the differences could be observed in a subset of pairwise comparisons of the same choice option with the same choice outcome (i.e., T1: 'reject'; T2: 'reject'). The data show a significant increase in signal change in the VMPFC ($M_{\Delta T2\text{-}T1} = .057$; $F(1,40) = 4.088$; $p = 0.049$). Together, these analyses demonstrate that valuation for a current option increases when alternative items were previously selected, independent of the choice outcome at T2.

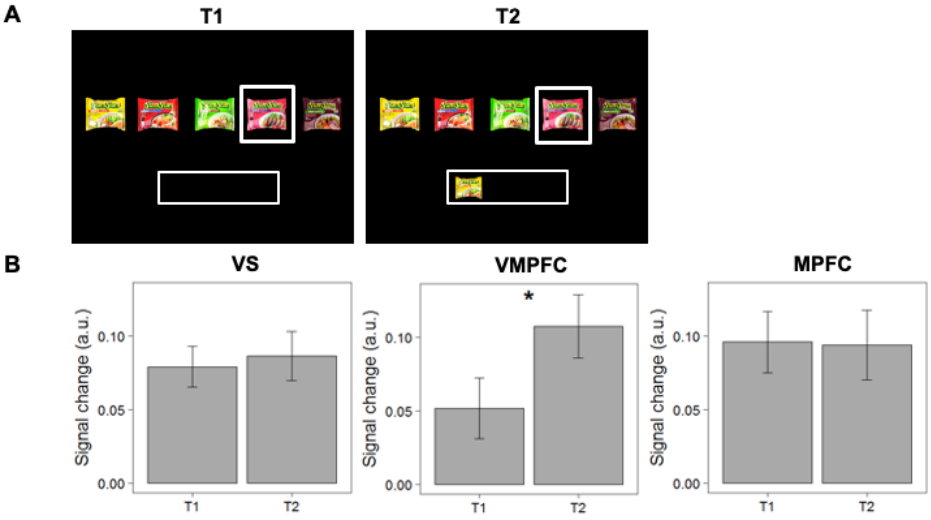

Figure 3.4. Test of the 'novelty-seeking' hypothesis. A) Example of a pairwise comparison of the first time an option was evaluated (T1) and the second time the same option was evaluated when another option was in the 'basket' (T2). B) Differences in signal change between T1 and T2 in the VS, VMPFC and MPFC. Error bars represent standard errors of the mean. The difference in signal change between T1 and T2 is only significant in the VMPFC ($F(1,40) = 5.281$, $p = .027$).

To assess to what extent the changes in neural response to 'satiation' and 'novelty-seeking' trials can be associated with distinct regions in the valuation network (VS or VMPFC), we ran a linear mixed model (with random intercepts for individuals) separately for 'satiation' and 'novelty-seeking' trials to test if the differences in signal change between the VS and VMPFC are significantly different. The results show that for 'satiation' trials this difference did not reach significance ($M_{\Delta \text{ VS (T2-T1) - VMPFC(T2-T1)}} = -.015$, $t(39.99) = -0.873$, $p = .388$), while for 'novelty-seeking' trials the neural response is indeed significantly stronger in the VMPFC as compared to the VS ($M_{\Delta \text{ VS (T2-T1) - VMPFC(T2-T1)}} = -.048$, $t(855) = -2.421$, $p = .016$).

3.5 Discussion

In this study, we provide novel insights into the mechanisms underlying choice diversification in portfolios. We propose that, as people make multiple selections from a menu of different options, the current state of their choice portfolio (i.e., the history of previously selected options) dynamically influences the utility of the options in the choice set, represented in the brain's valuation network. More specifically, we hypothesized that two different psychological mechanisms could drive diversification independently. People may diversify because (1) the utility of an option decreases when that option has been already selected ('satiation'), and/or (2) the utility of a non-selected option increases when alternative options have already been picked ('novelty-seeking'). We investigated how the neural valuation network might update the utility signal to enable these choice patterns.

Our behavioral data confirm that participants indeed diversify the majority of their choice portfolios. The choice data also demonstrate that some items were more likely to be rejected when they were already selected before, potentially indicating 'satiation', and that some items were more likely to be accepted once alternative items were selected, suggestive of 'novelty-seeking'.

The neural data provide evidence that these portfolio effects on choice are driven by valuation processes. That is, we find that activity in both the VS (NAcc) and the VMPFC – brain regions also shown in previous literature to contribute to value-based decision-making (e.g., Knutson and Cooper 2005; Delgado 2007; Levy and Glimcher 2012) – was modulated by the context of previously selected options. More specifically, our findings show that, most

prominently, activity in the VS decreased in response to options if they had been previously selected, aligning with the 'satiation' hypothesis. At the same time, we find an increase in activity in the VMPFC, in response to previously rejected options when other options have then been selected. This finding suggests that people also intrinsically have greater value for different or novel options as they are completing their choice portfolio, in line with the 'novelty-seeking' hypothesis. Thus, our results suggest that both the 'satiation' and 'novelty-seeking' mechanisms can drive diversification, and are represented at the neural level by regions within the brain's valuation network.

As we noted, in our analyses, we included all instances of a second viewing to test our 'satiation' and 'novelty-seeking' hypotheses. That is, to test the 'satiation' hypothesis, we compared responses to items that were accepted the first time, and accepted or rejected the second time. Similarly, to test the 'novelty-seeking' hypothesis, we compared responses to items that were rejected the first time, and accepted or rejected the second time. However, as we defined our ROIs based on the 'accept' > 'reject' contrast, comparing 'accept' or 'reject' trials at T1 with 'accept' and 'reject' trials at T2 within these ROIs could potentially inflate the results. We show that for 'novelty-seeking' trials, the results hold when we only select a subset of items that were rejected at T1 and also at T2 (so avoiding comparing 'accept' vs 'reject' trials). For 'satiation' trials we show that, even though the decrease in signal change in the VS when comparing items that were accepted at T1 and subsequently accepted again at T2 was not smaller than for items that we rejected at T2, the direct contrast between T1 and T2 for items that were accepted in both cases did not reach significance. It should be noted that this is a highly conservative test, as we do not necessarily hypothesize a difference within this particular subset of observations (i.e., a decrease in valuation should often lead to 'reject' decisions at T2). In addition, the observed effect for 'satiation' is in the hypothesized direction, and the lack of significance could be due to the limited number of observations that remain for this contrast.

In previous neuroimaging research, increased striatal activity - specifically in the nucleus accumbens - has been related to the anticipation of reward (e.g., Knutson et al. 2000). Hence, decreasing neural responses in the VS to a previously selected choice option may indicate an anticipation that repeated exposure to the given option will be less satisfying. While the strict definition of 'satiation' implies the diminishing marginal utility of an option after its repeated use or consumption (e.g., McAlister 1982) – which therefore cannot

predict diversification when making several choices at once – our findings do suggest that *anticipated* satiation, potentially encoded by the VS at the time of decision-making, could underlie choice diversification in portfolios. In a similar vein, research providing neurobiological support for marginal utility theory in a financial context has demonstrated that striatal activity in response to financial gains decreases in line with the increasing assets of individuals (Tobler et al. 2007). Note however that, although the decrease in valuation found here in response to previously selected options was most pronounced in the VS, it could not be reliably distinguished from the somewhat smaller decrease observed in the VMPFC, suggesting that (anticipated) satiation may be encoded rather broadly within the valuation system.

Our results suggest that the VMPFC might also play a different role in the context of portfolio choices, one more related to encoding the value of non-sampled options. Increased activity in the VMPFC has been related to value computation and executive control in previous literature. Consistently, the VMPFC is involved in predicting action outcomes, suggesting that this area encodes action-outcome associations in order to make selections according to the reward value ascribed to the respective actions (Hampton et al. 2006). For instance, the VMPFC has been found to encode a signal reflecting the comparison between a current and alternative actions, incorporating both the subjective value of the current action as well as the opportunity cost of not selecting the alternative actions (Boorman et al. 2009; Boorman et al. 2013). Thus, the VMPFC might be implicated in the assessment of whether or not it is worth adapting or maintaining decisions. While the VMPFC has been found to encode relative value of chosen options in related multi-alternative sequential choice tasks, such as foraging paradigms (e.g., Kolling et al. 2012), it should be noted that the present choice paradigm critically differs from these tasks in that there are no direct costs associated with choosing a different option, or feedback provided to indicate that there is a change in the actual value of the repeatedly selected item. The VMPFC has also been related to affective foresight, mediating mental simulations of the affective value of future outcomes (Bechara et al. 2000; Bechara and Damasio 2005). In the current study, the observed VMPFC signal in response to an option that is different from previously selected options in a particular choice portfolio might reflect a motivation to change course, based on the predicted value of the outcome of that decision (e.g., more variety).

Taken together, our results show, to some extent dissociable, roles for the VS and the VMPFC in value-based portfolio choices. We propose that the VS might be more strongly involved in 'simple' option-by-option valuation, with a decrease in responsivity reflecting anticipated satiation for the given option, while the VMPFC is (also) recruited for top-down control, with an increase in activity representing the high value of novelty or change. Triggered by different states of the choice portfolio, our findings suggest that these mechanisms can drive diversification via different processes.

Our results thus suggest that the bundle of the previous selections, the essential element that distinguishes portfolio choices from single choices made in isolation, can strongly impact how the brain values choice options. This indicates that making several selections together can prompt decision-makers to choose options that optimize the overall experience of the portfolio, instead of considering the experience of the options when taken in isolation (see also Read et al. 1999). As reflected in our liking data, this can sometimes lead to seemingly 'sub-optimal' choices, such as when a bundle consisting of a preferred and a somewhat less preferred option (e.g., strawberry and banana yogurt) is chosen over a bundle that consists of the preferred option twice (e.g., two tubs of strawberry yogurt). Our data here suggests that the interdependence of the (anticipated) experience of selected options might receive greater attention when making portfolio choices. The current research thus provides both behavioral and neuroscientific evidence of this interdependence, describing diversification behavior driven by both 'satiation' and 'novelty-seeking' mechanisms.

Chapter 4
Neural Responses to Ad Appeals[2]

[2] This chapter is based on Couwenberg, L. E., Boksem, M. A. S., Dietvorst, R. C., Worm, L., Verbeke, W. J. M. I., & Smidts, A. (2017). Neural responses to functional and experiential ad appeals: Explaining ad effectiveness. *International Journal of Research in Marketing*, *34*(2), 355–366. https://doi.org/10.1016/j.ijresmar.2016.10.005

4.1 Abstract

Despite the large body of research that has investigated the effect of ad appeals of television advertisements on consumers' internal responses and behavior, our understanding of how different ad appeals are processed remains limited. Complementing existing literature with novel insights from neuroimaging techniques can be valuable, providing more immediate insights into implicit mental processes. The present study explores the neural responses to functional and experiential executional elements in television advertisements by using functional magnetic resonance imaging (fMRI). Comparing a unique set of different commercials for the same brand enabled examination of the influence of differences in ad appeal on brain responses and subsequent advertisement effectiveness. Findings show that functional and experiential executional elements engage different brain areas, associated with both cognitive and emotional processes, and that the extent to which these particular brain networks are activated and interact, is associated with higher ad effectiveness.

4.2 Introduction

More than sixty years after the emergence of television advertising, the debate of what constitutes a successful commercial is still ongoing (Heath & Stipp, 2011). A large body of prior research has enriched our understanding of the effect of different ad appeals in television advertisements on cognitions, emotions, and behavior. The literature indicates that internal processes in response to ad appeals are important indicators of ad effectiveness. For instance, consumers' feelings in response to ads have been shown to have a positive influence on brand attitudes (e.g., Edell & Burke, 1987). Research on internal responses to ads has been conducted primarily using self-report metrics, which have provided useful insights, but do have several limitations. For instance, research has shown that people are limited in reflecting on their internal states (e.g., Nisbett & Wilson, 1977). Hence, the more complex cognitive or emotional responses to dynamic marketing stimuli might be difficult to capture with self-report alone, and could thus have been overlooked. Given the significant role of internal processes in driving ad efficacy (e.g., Pham, Geuens, & De Pelsmacker, 2013) a more accurate measurement of these processes is imperative, providing a richer understanding of consumers' responses to different advertisement

executions. Through this increased understanding, the creative development of ads can be further optimized.

More implicit and innovative methods to measure internal responses, such as neuroimaging (i.e., functional magnetic resonance imaging (fMRI)), can be of value here, providing online insight into ongoing mental processes unbiased by self-report (Yoon et al., 2012). In the current study, we explore how novel insights from neuroimaging techniques can advance our understanding of how different ad appeals of a set of television commercials for the same brand are processed by consumers and how these processes are, in turn, related to advertisement effectiveness in an independent sample of consumers.

4.2.1 Functional and Experiential Approaches in Advertising

Broadly speaking, an advertising appeal – the central idea of a message that highlights specific attributes of the product – can be described in terms of its functional and experiential elements (e.g., Zarantonello, Jedidi, & Schmitt, 2013). In the literature, related distinctions have been defined and referred to using varying terminology, such as informational and transformational (Rossiter & Percy, 1987), utilitarian and value-expressive (Johar & Sirgy, 1991) and somewhat broader concepts as hard-sell and soft-sell (Okazaki, Mueller, & Taylor, 2010). Although many of these distinctions relate to a more general rational/emotional framework of advertising message strategy (Albers-Miller & Stafford, 1999), in the current study we will specifically focus on the distinction between functional and experiential ad appeals. Ads with a predominant functional appeal typically convey a message that focuses on factual information to explain why the consumer should like and buy a product. That is, the functional elements of an advertising message relate to a rational or utilitarian focus on product features, by including references to the product attributes, its use and performance, as well as the benefits and value that come with these features (Abernethy & Franke, 1996). In contrast, one of the key ideas of an experiential advertising appeal is that value does not only reside in the advertised good and its utilitarian and functional benefits, but that value also lies in the emotional and experiential elements associated with the good, and in the (indirect) experience of it (e.g., through advertisements; Holbrook & Hirschman, 1982; Schmitt & Zarantonello, 2013). Accordingly, a typical experiential appeal associates the product with desirable images or symbols and depicts what kind of experience results from using the brand. The experiential elements of an ad particularly evoke sensations, feelings,

emotions, imaginations and behavioral responses (Brakus, Schmitt, & Zarantonello, 2009).

The issue of when a particular type of appeal should be employed has been extensively studied in the marketing and advertising literature. Researchers have posited that the effectiveness of the appeal largely depends on the advertised good itself. That is, several studies suggest that the appeal should match the product type, as, for instance, ads with a utilitarian focus are found to be more effective for utilitarian products (e.g., Johar & Sirgy, 1991). In some cases, however, advertisers may adopt an appeal that is rather incongruent with the product type. It has been shown that employing a more creative appeal with metaphorical instead of literal information for utilitarian products enhanced perceptions of sophistication and excitement, although at the cost of reduced perceptions of sincerity (Ang & Lim, 2006). Furthermore, advertisers may use incongruent (e.g., irrelevant or unexpected) messages to grab consumers' attention. Research on print ads shows that consumers' memory for information in the ad appeared to benefit most from incongruence created with unexpected but relevant information (Heckler & Childers, 1992).

Many ad appeals – also the ones of interest in the current study – contain, to some extent, both functional and experiential elements. Some research suggests that mixing emotional elements with rational information is rather ineffective. For instance, research on donation behavior shows that a narrative description of an identifiable victim led to higher donations than when the description was combined with statistical information about the cause (Small, Loewenstein, & Slovic, 2007). Moreover, eye-tracking studies of individuals viewing television commercials found that people were more likely to discontinue viewing when ads were both entertaining (i.e., warm, amusing, and playful) and informative (Woltman Elpers, Wedel, & Pieters, 2003). However, other studies have suggested that emotional content would be beneficial to any ad, independent of product category or level of involvement (e.g., Pham, Geuens, & De Pelsmacker, 2013).

4.1.2 Processing Functional and Experiential Ad Appeals

As research on the persuasiveness of ad appeals has yielded inconclusive insights, it is crucial to understand how functional and experiential ad appeals are processed by consumers. Traditionally, the two approaches are believed

to be effective through different routes to persuasion: targeting affect with experiential executional elements, and targeting cognitions with functional executional elements. Research suggests that positive brand attitude formation for information-based ads is predominantly driven by deliberate evaluations and beliefs (Yoo & MacInnis, 2005). Functional information may reduce uncertainty about the advertised product or brand (Abernethy & Franke, 1996). In contrast, positive brand attitudes for emotion-evoking ads may be predominantly driven by feelings (Yoo & MacInnis, 2005). Research has revealed that ad-evoked feelings of warmth exert a positive influence on ad liking and purchase intent (Aaker, Stayman, & Hagerty, 1986). How ad-evoked feelings affect positive brand attitudes has been widely studied in the literature, resulting in a range of different possible explanations. For instance, ad-evoked feelings may be associatively incorporated in brand evaluations through evaluative conditioning (e.g., De Houwer, Thomas, & Baeyens, 2001; Jones, Olson, & Fazio, 2010), or may affect brand evaluations indirectly through a more inferential process of affect-as-information (e.g., Schwarz & Clore, 1983).

More recent research has related differences in the processing of experiential and functional features to processing fluency (i.e., the subjective ease with which people process information; e.g., Alter & Oppenheimer, 2009). Processing-fluency theory distinguishes between fluent processing, which occurs spontaneously, and less-fluent processing, which is more deliberate and effortful. Brakus, Schmitt, and Zhang (2014) show that consumers can process experiential attributes (sensory and affective) both fluently and non-fluently. As the authors note, fluent processing of an experiential attribute is likely to occur when a consumer spontaneously receives an impression of the stimulus and responds without elaborating. Non-fluent processing of experiential attributes will occur when consumers do cognitively elaborate on such attributes. Their findings suggest that consumers will only process experiential attributes fluently when these experiential attributes are expected in the specific context, and that fluent processing is positively related to product liking. In contrast, their findings also suggest that consumers process functional attributes always deliberately, and need time to extract value from them.

4.2.3 The Value of Neuroimaging in Measuring Emotional and Cognitive Processes

Conventional measures that have been used to acquire insights into consumers' internal responses to different ad appeals and their specific elements are generally based on self-report measures, such as attitude to the ad and ad-evoked feelings (e.g., MacKenzie, Lutz, & Belch, 1986; Pham, Geuens, & De Pelsmacker, 2013). These self-report measures are often based on an information processing framework that assumes that people are capable of introspecting successfully on their cognitions and feelings, and that these in turn relate to their choice. Relying on such measures might be risky in contexts in which the consumer is unaware of, or unable to report on, the actual ongoing cognitive and emotional processes. Importantly, research has shown that attempts to report on one's cognitive processes might actually change these processes (Dijksterhuis, 2004; Nisbett & Wilson, 1977; Wilson & Schooler, 1991). Moreover, most conventional methods do not allow for online measurement of internal states at the time of exposure to a marketing stimulus. Consequently, the time interval between exposure and evaluation might further increase susceptibility to biased reflections or self-justification processes. Hence, given the important role of internal processes in driving ad efficacy, more implicit methods that can increase the understanding of these immediate internal responses to advertisement materials are valuable and should be further explored.

Neuroimaging methods, such as fMRI, can serve as a valuable complement to conventional methods, providing insights into implicit processes that are typically difficult to access using other approaches. Using fMRI, the brain's response to marketing stimuli can be assessed in the form of a blood oxygenation level-dependent (BOLD) measurement, which is taken as a proxy for neural activation. Neuroimaging has been successfully applied to demonstrate dissociations between psychological processes and has revealed novel insights into how people process information. For instance, Sanfey et al. (2003) have demonstrated the value of fMRI in investigating the relative contributions of cognitive and emotional processes to decision-making, revealing activity in brain regions related to both emotion and cognition in response to unfair offers in an ultimatum game and thereby providing novel insights into the role for emotions in economic decision-making. Although neuroimaging has challenges of its own (Plassmann, Venkatraman, Huettel, & Yoon, 2015), complementing conventional methods with neuroscience

technology could set the stage for higher levels of sophistication in our understanding of how ad appeals are processed by consumers.

4.2.4 Rationale for Current Study

In this paper, we aim to build upon the extensive body of research on ad appeals by using innovative neuroimaging methods to advance our understanding of the different cognitive and emotional processes associated with advertising executional elements. Comparing a unique set of different television commercials for the same brand enabled us to investigate the influence of differences in advertisement appeal, in terms of its functional and experiential executional elements, on brain responses and subsequent advertisement effectiveness. In our experimental design, we combine data from three independent samples: (1) an fMRI neural focus group, to measure immediate neural responses to the television commercials; (2) a large sample of consumers in the population, to assess ad effectiveness for each commercial; and (3) a sample of advertising experts who assessed each commercial's appeal. Advertising effectiveness was measured here by the consumer's online information search behavior in direct response to a television commercial (i.e., click through rate to the product website). Hence, our main objectives were to explore the neural processes evoked by functional and experiential executional elements in advertisements and to demonstrate how these processes relate to ad effectiveness in an independent group of consumers.

4.3 Materials and Methods

4.3.1 Participants

4.3.1.1 FMRI group

Twenty-five participants were recruited for the fMRI experiment. We selected a heterogeneous audience for our commercials of interest: our group of participants varied in gender (12 male), age (range: 23 - 48 years; M = 36.52) and in educational background (highest qualification: high school = 4%; lower vocational education = 36%; higher vocational education = 44%; university (graduate level) = 16%). One male participant was excluded from the analyses,

because he did not feel comfortable in the scanner and could not complete the experiment.

4.3.1.2 Population group

The population sample consisted of 1239 participants and was comparable to the fMRI sample with respect to gender (624 male), age (range: 25 – 55 years; M = 41.77) and educational background (highest qualification: elementary school or less = 6%; high school = 23%; lower vocational education = 32%; higher vocational education or university (undergraduate level) = 25%; university (graduate level) = 14%). Participants were randomly selected from a consumer panel hosted by a market research company.

4.3.1.3 Expert panel

We recruited nine independent professionals with substantial knowledge and working experience (all > 7 years) in advertising, marketing or communication as expert judges to evaluate the execution of each commercial on its functional and experiential dimensions.

4.3.2 Materials

Our stimuli consisted of a set of eleven television commercials for the same brand and product (i.e., a well-known muscle and joint gel), which were developed in the context of a competition between small and medium sized advertising agencies. The selected commercials were of comparable professional quality and equal length (all 20 seconds).

Although research has shown that the brain encodes low-level features of visual stimuli independently from higher-level features such as object properties and affective content (Chikazoe, Lee, Kriegeskorte, & Anderson, 2014), we checked for any variation in low-level visual features between commercials that could potentially covary with variables of interest in this study (i.e., the expert-rated executional elements and the ad effectiveness measure). Using the Image Processing Toolbox in Matlab 2012b, we extracted low-level visual features separately for each commercial to test for uniformity across commercials with respect to luminance (i.e., average pixel intensity per frame), luminance contrast (i.e., the standard deviation of pixel intensity per frame) and the amount of movement and cuts (i.e., the pixel-by-pixel

correlation relative to the previous frame; the cross-frame correlation). All measures were computed on a frame-by-frame basis and then averaged over the commercial. One-sample Kolmogorov-Smirnov tests indicated uniformity across the commercials for luminance and luminance contrast (for both $p >$ .05). Although cross-frame correlations were not uniformly distributed across commercials ($p <$ .05), they did not correlate significantly with the expert-rated executional elements or the ad effectiveness measure. These results indicate that any findings related to our variables of interest cannot be attributed to differences in low-level visual features.

Furthermore, the commercials contained a highly similar voice-over text, but differed markedly in terms of specific execution style. We differentiated between the executional elements of the commercials using the expert judgments scale from Zarantonello, Jedidi, and Schmitt (2013), which consists of nine formative items that pertain to the functional and experiential dimensions of an ad, respectively. The expert judges evaluated five functional elements of the commercials by indicating on a four-point scale to what degree the commercial focuses on product attributes ("To what degree does the ad focus on product attributes (i.e., the formulation or ingredients of the product and its features)?"), product applications (i.e., how the product has to be applied or used), product performance (i.e., what the product can do and its efficacy), functional benefits (i.e., the advantages for the consumer), and functional value (i.e., value for money or convenience of the product), respectively (1= not at all present to 4 = strongly present). Finally, the experts indicated how functional the commercial was overall (i.e., a functional ad is an ad that includes the above and related characteristics; 1 = not at all functional to 4 = strongly functional). The experiential elements were assessed on four items that capture the degree to which the commercial uses or appeals to sensory elements ("To what degree does the ad use or appeal to sensory elements (i.e., colors and exciting visuals, music, touch, smell)?"), feelings and emotions (i.e., all kinds of feelings and emotions, either positive or negative), imagination and mental stimulations (i.e., thinking in a different, original and innovative way, approaching things from a new angle), and behaviors and actions (i.e., physical activities, specific actions, bodily experiences), respectively (1 = not at all present to 4 = strongly present). The experts also indicated how experiential the commercials were overall (i.e., an experiential ad is an ad that includes the above and related characteristics; 1 = not at all experiential to 4 = strongly experiential).

An inter-rater reliability analysis using the intraclass correlation statistic was performed, separately for each commercial, to determine consistency among raters. The median intraclass correlation was .82 (range: .57 - .95) indicating a satisfactory inter-rater reliability. The five items on the functional dimension (i.e., "*Product Attributes*", "*Product Application*", "*Product Performance*", "*Functional Benefits*" and "*Functional Value*") and the four items on the experiential dimension (i.e., "*Sensory Elements*", "*Feelings and Emotions*", "*Imagination and Mental Stimulation*" and "*Behaviors and Actions*") constituted the executional elements of interest for this study.

4.3.3 Procedures

4.3.3.1 FMRI study

Participants in our fMRI study passively (i.e., without any specific task) viewed all commercials four times (each commercial was shown twice within one run, two runs in total) in random order while their brain activity was recorded. The commercials were projected onto a screen at the back of the fMRI scanner, and participants viewed them through a mirror attached to the head coil. Participants wore headphones to be able to hear the auditory voice-over of each commercial. In-between the two runs, participants viewed a series of commercials for a branded food product that are not of interest for the current experiment. The experiment started with a 10 s fixation screen, to allow for longitudinal relaxation time equilibrium of the BOLD response. The presentation of each commercial was alternated with the same 10 s fixation screen. Each run lasted 12 minutes and total scanning time, including the anatomical scan, was approximately 55 minutes.

4.3.3.2 Population study

Participants in the population group were randomly assigned to passively view one of the eleven commercials in an online survey. After viewing the commercial, we provided participants with a choice to click through to the product website for more information and potential purchase of the product, or to finish the survey. On the product website, the product was offered at a discount, and participants were informed about the specific discount before they made the decision to click through or not.

4.3.3.3 Expert judgments

The expert judges viewed all commercials in random order, and after viewing each commercial they filled out the expert judgments scale to evaluate its specific execution style. They were allowed to view each commercial several times to enable adequate assessment of its characteristics.

4.3.4 FMRI Data Acquisition Parameters

We used a 1.5T Siemens MRI scanner with a Siemens circular polarized head array coil to measure changes in BOLD response. Volumes were acquired with an interleaved slice acquisition and a T2*-weighted echo-planar imaging (EPI) pulse sequence (repetition time (TR): 3000 ms; echo time (TE): 40 ms; flip angle: 90°; matrix size: 80x80; resolution: 3x3x3.3 mm; field of view (FOV): 240 mm). In addition, we acquired T1-weighted high-resolution anatomical images using a MP-RAGE sequence (TR: 2040 ms; TE: 3.93 ms; flip angle: 15°; matrix size: 256x256; resolution: 1x1x1 mm; FOV: 256 mm).

4.3.5 FMRI Data Preprocessing

We preprocessed and analyzed the neuroimaging data using standard software (SPM8, Wellcome Department of Cognitive Neurology, London, UK). To correct for head motion, the functional images were realigned to the mean image within each run and motion parameters were added to the first-level general linear models as regressors of no interest. Functional images were coregistered to the anatomical image, spatially normalized to the Montreal Neurological Institute (MNI) template and spatially smoothed with a Gaussian kernel (9x9x10 mm full width at half maximum).

4.3.6 Statistical Analyses

To investigate the neural processes evoked by functional and experiential executional elements and how these processes relate to ad effectiveness, we conducted a series of statistical analyses (see Figure 4.1 for a schematic overview)[3]. First, we assessed which of the expert-rated executional elements

[3] Although we assume a mediation model, a formal multi-level mediation analysis could not be performed on these datasets, as both the independent and the dependent variable were measured on the commercial-level, and thus do not vary across participants in the fMRI sample.

were significantly related to population-level ad effectiveness (see Figure 4.1, relationship *a*). Our population-level data provided two potential measures of ad effectiveness: the decision to click-through to the product website and actual purchase of the advertised product. As our commercials advertise a utilitarian product type (i.e., a muscle gel), the decision to purchase is likely to be accompanied by an actual 'need' for this product (i.e., muscle pain). As this specific 'need' was neither required nor assessed within our sample, we did not expect the number of purchases to be particularly high. Correspondingly, the data showed that the total percentage of participants across all eleven commercial-conditions that purchased the product was only 1%. Taking the characteristics of our product type into account, we used click-through rate (CTR; i.e., the percentage of participants in the population group who clicked through to the product website) as our core measure of ad effectiveness. Click-through behavior reflects participants' interest in the product as evoked by the advertisement, which could be a precursor of future purchase. The percentage of participants in our population group clicking through to the product website after viewing one of the commercials ranged from 6.20% to 16.35% (M = 9.67%). As a second step, we examined the brain regions engaged by the functional and experiential executional elements (see Figure 4.1, relationship *b*). Third, we analyzed whether activity in these brain regions while participants were viewing the commercials was predictive of CTR (see Figure 4.1, relationship *c*).

More specifically, to assess the relationship between the nine executional elements and population-level CTR (i.e., relationship *a* in Figure 4.1), we ran a stepwise linear regression model with the expert-rated executional elements (standardized per expert) as predictors in the model and CTR as the dependent variable. Those executional elements that were most predictive of ad effectiveness constituted the elements of interest in the following analyses.

The fMRI data analysis proceeded in several steps. To investigate the neural correlates of the executional elements identified in the previous step (i.e., relationship *b* in Figure 4.1) we first estimated a first-level general linear model (GLM) for each participant separately. For each run, neural responses to the commercials were modeled with a boxcar regressor based on the twenty-two onset times of all commercials, convolved with a canonical hemodynamic response function (HRF). We defined a parametric modulator to this main regressor which consisted of the mean-centered expert-rated executional elements for each commercial. The linear expansion of the parametric

modulator predicted that as the rating values increased, there would be a related increase in brain activity. Six motion parameters (capturing the movement of subjects in the scanner) were added to the models as regressors of no interest. In order to remove non task-related low frequency signal changes, we included three additional nuisance regressors which capture the time-course of activity in areas that should not show any task-related activity (i.e.; in white matter, cerebrospinal fluid and the area outside the brain). Next, we created contrast images summarizing differences in brain activity as evoked by the commercials that correlate with each of the expert-rated executional elements. The beta maps resulting from fitting each of these parametric regressors were tested at the group level as one-sample t-tests.

To assess whether the neural activity within the regions related to the executional elements of interest was predictive of ad effectiveness (i.e., relationship *c* in Figure 4.1), we constructed regions-of-interest (ROIs) within those identified brain regions (6 mm radius spheres around the most significant voxels), and extracted parameter estimates from the selected voxels using MarsBaR (Brett, Anton, Valabregue, & Poline, 2012). We included these parameter estimates as fixed effects in a multi-level linear regression model with random intercepts for participant and run, and with CTR as response variable.

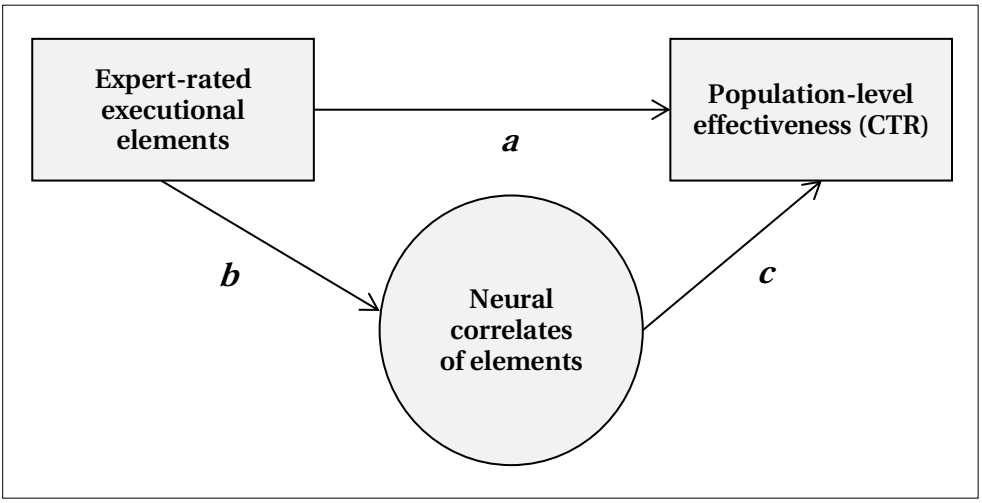

Figure 4.1. Schematic overview of statistical analyses.

4.4 Results

4.4.1 Identifying the Most Effective Executional Elements

The results of the stepwise linear regression model, assessing the relationship between the expert-rated executional elements and population-level CTR (i.e., relationship *a* in Figure 4.1), show that a model including both the functional element "*Functional Benefits*" as well as the experiential element "*Imagination and Mental Stimulation*" has the best fit with the observed data ($R^2 = .169$, $F(1,96) = 5.204$, $p < .05$). See Table 4.1 for the model coefficients. None of the remaining elements added significantly to this model ($p > .11$).

As these results indicate, the executional elements "*Functional Benefits*" and "*Imagination and Mental Stimulation*" are independently related to ad effectiveness, which thus suggests that those commercials that do not only demonstrate the functional benefits of the product (i.e., the advantages for the consumer), but also appeal to imagination and mental stimulation (i.e., thinking in a different, original and innovative way, approaching things from a new angle) are most effective here in motivating online search behavior. See Figure 4.2 for a graphical representation of each of the eleven ads on "*Functional Benefits*" and "*Imagination and Mental Stimulation*", and its resulting CTR.

Table 4.1. Executional Elements Predicting Click-Through Rate

Dependent	Step	Predictor(s)	Coefficients		Change Statistics		
			β	*t*	*R Square Change*	*Total R Square*	*F(df1,df2)*
CTR	1	Functional Benefits	.352	3.707***			
					.124	.124	13.739(1,97)***
	2	Functional Benefits	.299	3.117**			
		Imagination and Mental Stimulation	.219	2.281*			
					.045	.169	5.204(1,96)*

Notes: *** $p < .000$; ** $p < .01$; * $p < .05$. Forward stepwise linear regression with probability to enter the model <= .05. Expert-ratings were standardized for each expert.

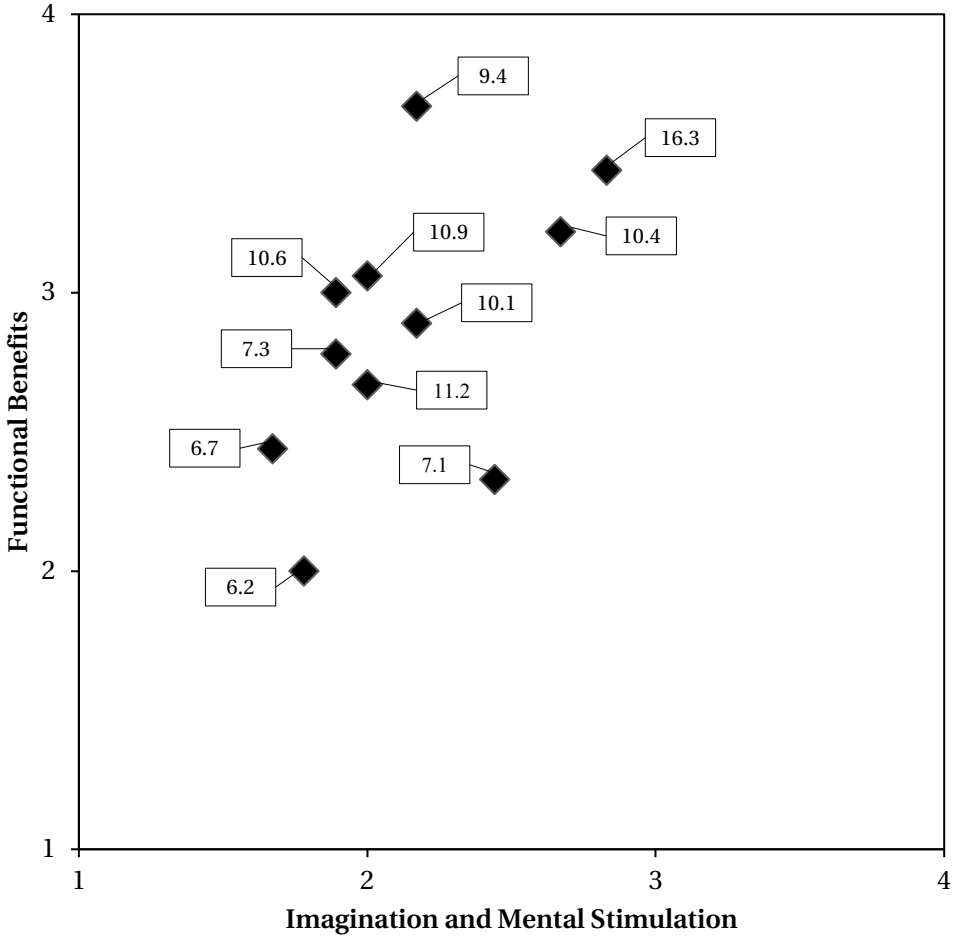

Figure 4.2. Functional and Experiential Elements driving Ad Effectiveness. Scatterplot of mean expert ratings on items "*Functional Benefits*" and "*Imagination and Mental Stimulation*" for the eleven commercials. Data labels represent the percentage of people in the population group clicking through to the product website in response to the commercial.

4.4.2 Neural Responses to Functional and Experiential Elements

To provide insight into the neural responses to experiential and functional elements (i.e., relationship *b* in Figure 4.1), we explored the neural substrates associated with the two most effective executional elements as identified by our previous analyses. The results reveal that the more prominently the functional element "*Functional Benefits*" is present in the commercials, the higher the activity in, predominantly, the temporal cortex, including the inferior temporal gyrus (ITG), the middle temporal gyrus (MTG) and the parahippocampal gyrus (PHG), and to a lesser extent the dorsolateral prefrontal cortex (DLPFC; the middle frontal gyrus (MFG)). For a complete overview of these results, see Table 4.3A and Figure 4.3A. Additionally, the stronger the commercials appeal to the experiential element "*Imagination and Mental Stimulation*" the higher the activity in, predominantly, the DLPFC (i.e., precentral gyrus extending into the inferior frontal gyrus (IFG) and the MFG), and to a lesser extent the temporal cortex (i.e., ITG and MTG). See Table 4.4A and Figure 4.3B for a more detailed overview of these results.

As the previous results reveal that similar brain regions are engaged by the functional and the experiential executional elements (i.e., both elements engage the temporal cortex and the DLPFC), we additionally examined to what extent these executional elements are processed independently from each other. To this end, we corrected the signal increase related to "*Functional Benefits*" for activations related to "*Imagination and Mental Stimulation*" and vice versa. First, we ran a general linear model including two parametric modulators: the first one modelling "*Imagination and Mental Stimulation*" and the second one modelling "*Functional Benefits*". The parametric modulators were serially orthogonalized, meaning that any variance associated with the functional element was removed when reporting activity related to the experiential element. Thus, the neural correlates of "*Functional Benefits*" resulting from fitting this model reflect unique neural responses that are independent from those related to the experiential element. Interestingly, the results show that activation in the temporal cortex (e.g., MTG, ITG and PHG) was uniquely related to the functional element, whereas activity in the DLPFC was not (see Table 4.3B for an overview of the results). Similarly, to investigate to what extent the experiential element was processed independently from the functional element, we ran another general linear model with two parametric modulators, the first one modelling "*Functional Benefits*" and the second one modelling "*Imagination and Mental*

Stimulation". The results indicate that activity in the right DLPFC, but not in the temporal cortex, was uniquely related to the experiential element (see Table 4.4B for an overview of the results).

Table 4.3. Neural Correlates of Functional Benefits

Region	Hemisphere	MNI Coordinates			Cluster Size	Z
		x	y	z	[k voxels]	
A) Functional Benefits						
Inferior Occipital Gyrus ext. into Middle Temporal Gyrus and Inferior Temporal Gyrus	L	-45	-79	-7	782	5.53*
DLPFC: Middle Frontal Gyrus	R	39	2	39	191	4.77*
Cerebellum	L	-12	-70	-24	70	4.72*
Middle Temporal Gyrus	R	57	-46	3	527	4.62*
Parahippocampal Gyrus	L	-30	-1	-24	25	4.62
B) Functional Benefits corrected for Imagination and Mental Stimulation						
Inferior Occipital Gyrus ext. into the Middle Temporal Gyrus and Inferior Temporal Gyrus	L	-45	-70	-13	830	5.60*
Middle Temporal Gyrus	R	45	-58	6	395	5.17*
Middle Occipital Gyrus	L	-12	-94	-1	102	4.35
Fusiform Gyrus	R	42	-46	-20	38	4.14*
Cingulate Gyrus	R	18	11	29	12	3.51
Parahippocampal Gyrus	L	-30	-1	-24	10	3.51
Cuneus	R	24	-82	16	12	3.36

Notes: Regions listed exceed threshold of $p < .001$ uncorrected, with at least 10 contiguous voxels. Regions denoted with an asterisk exceeded threshold of $p < .05$ FWE corrected on the cluster-level. Z-values for each peak are given. Abbreviations: R = Right, L = Left, DLPFC = dorsolateral prefrontal cortex. N = 24.

Table 4.4. Neural Correlates of Imagination and Mental Stimulation

Region	Hemisphere	MNI Coordinates			Cluster Size	Z
		x	y	z	[k voxels]	
A) Imagination and Mental Stimulation						
DLPFC: Precentral Gyrus ext. into Inferior Frontal Gyrus and Middle Frontal Gyrus	R	54	5	32	109	4.47*
Cerebellum	L	-15	-76	-37	62	4.45*
Middle Temporal Gyrus	R	57	-28	-7	27	4.08
Inferior Temporal Gyrus	R	54	-49	-7	12	3.69
Middle Temporal Gyrus	L	-48	-55	-4	11	3.56
B) Imagination and Mental Stimulation corrected for Functional Benefits						
DLPFC: Inferior Frontal Gyrus	R	51	5	32	16	3.92
Medial Prefrontal Gyrus	L	-6	47	26	13	3.38

Notes: Regions listed exceed threshold of $p < .001$ uncorrected, with at least 10 contiguous voxels. Regions denoted with asterisk exceeded threshold of $p < .05$ FWE corrected on the cluster-level. Z-values for each peak are given. Abbreviations: R = Right, L = Left, DLPFC = dorsolateral prefrontal cortex. N = 24.

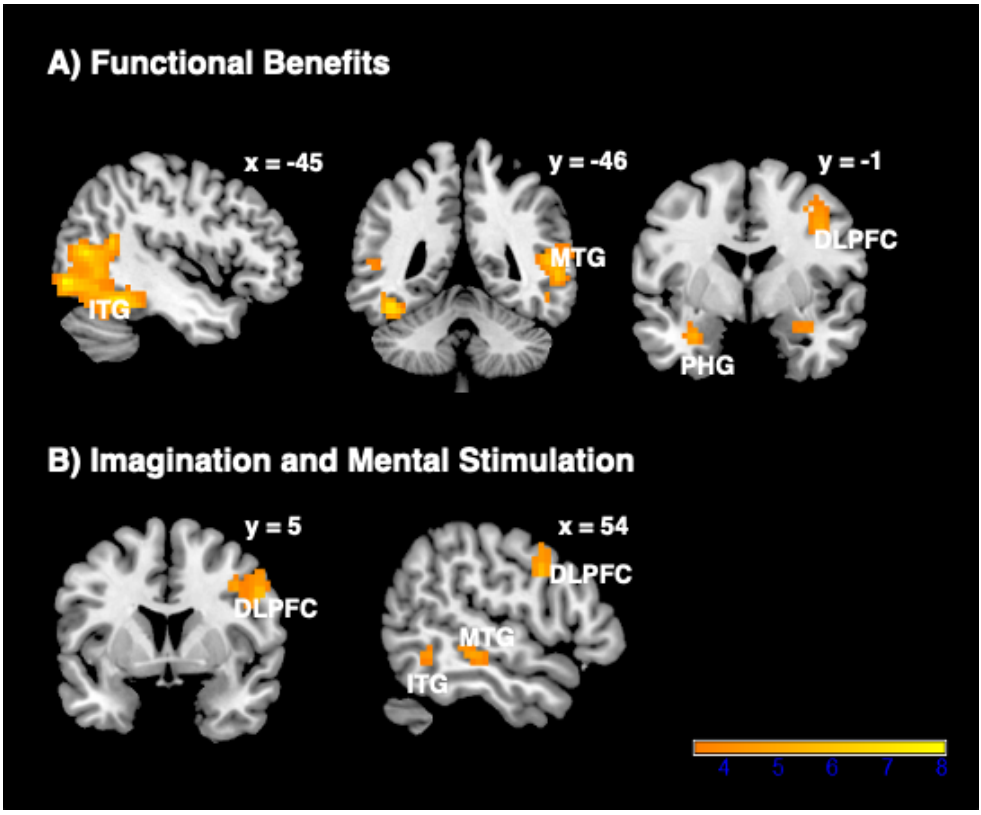

Figure 4.3. A) neural correlates of "*Functional Benefits*"; B) neural correlates of "*Imagination and Mental Stimulation*". Displayed brain activity exceeds threshold of $p <$ .001 uncorrected, with at least 10 contiguous voxels. Color bar represents t-statistics. See Table 4.3 and 4.4 for more details not shown here.

4.4.3 Neural Predictors of Click-Through Rate

Next, we examined how activity in the previously identified brain regions relates to our ad effectiveness measure (i.e., relationship *c* in Figure 4.1). We constructed two ROIs within those brain regions that we found to be both uniquely and most significantly related to the respective functional or experiential element. One ROI was constructed within the brain region that was most strongly engaged by the element "*Functional Benefits*" (i.e., the left ITG; we took a sphere of 6 mm radius around the peak voxel (slightly shifted dorsally to make sure it fell entirely within the brain): x = -45, y = -68, z = -11), and one within the brain region that was most strongly engaged by *"Imagination and Mental Stimulation"* (i.e., the right DLPFC; a sphere of 6 mm radius around the peak voxel: x = 51, y = 5, z = 32).

The results of the multi-level linear regression model, assessing the relationship between the activity within these two ROIs and population-level CTR, reveal that neural activity within the DLPFC ROI is a significant predictor of CTR (b = .014, $p < .05$), and that neural activity within the ITG ROI is a directionally significant predictor of CTR (b = .008, $p = .086$). These ROIs significantly predict CTR as compared to an intercept-only model (χ^2 (2) = 10.745, $p < 0.005$). Hence, the extent to which the brain regions associated with the most effective functional and experiential elements were activated while viewing the commercials, predicted the successfulness of the commercials in stimulating click-through behavior. See Table 4.5 for an overview of the fixed predictor effects.

To explore whether brain regions other than those activated by the two most effective functional and executional elements might also be related to higher CTR, we ran another general linear model on the fMRI data and included the mean-centered CTR values for each commercial as a parametric modulator in the model, and plotted the resulting neural correlates of CTR at different thresholds of significance. As illustrated in Figure 4.4, the ITG and DLPFC are the only two regions that are positively correlated with CTR, even at very liberal significance levels (i.e., from $p < .01$, uncorrected). These results suggest that this particular combination of brain regions – those regions engaged by the functional element (i.e., ITG) and the experiential element (i.e., DLPFC) – is related to higher ad effectiveness in an independent sample.

Table 4.5. Neural Predictors of Ad Effectiveness

Dependent	Predictors	Fixed Effects			
		b	*SE*	*t*	*p*
CTR	ITG ROI	0.008	0.004	1.794	0.086
	DLPFC ROI	0.014	0.005	2.694	0.014

Notes: Results of the multi-level linear regression model with random intercepts for run and participant.

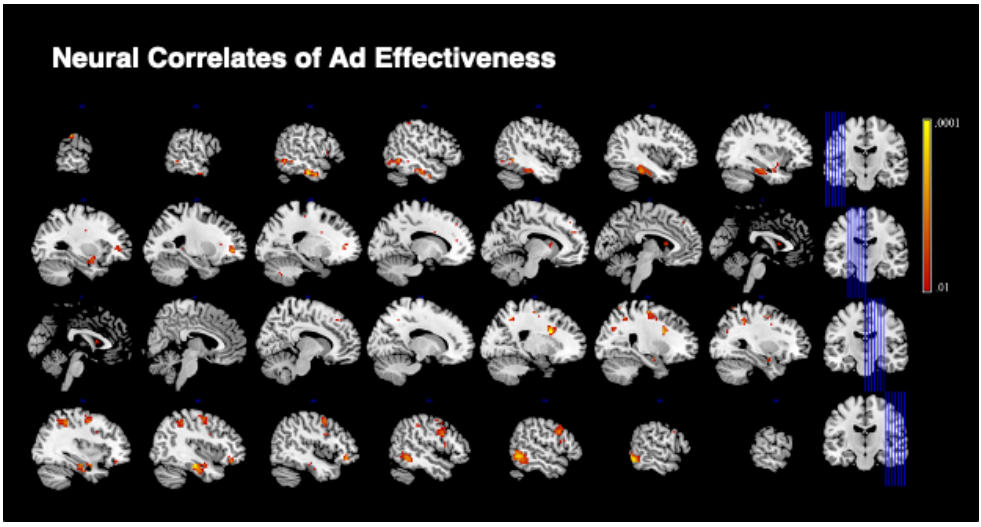

Figure 4.4. Neural activation map for the parametric modulation of population-level CTR with the BOLD response. Each image represents a slice of the brain (location of the slices is indicated in blue on the rightmost images). Resulting t-values for each voxel were transformed to –log10 *p*-values to improve visualization and interpretability. Color bar represents the corresponding *p*-values. The upper and lower rows reveal activations in the temporal cortices; de lower row also reveals activations in the right DLPFC.

4.4.4 Functional Connectivity in Response to More Effective Commercials

To further improve our understanding of the neural responses to functional and experiential executional elements and how they relate to ad effectiveness, we conducted a psycho-physiological interaction (PPI) analysis using a generalized form of context-dependent PPI (gPPI; McLaren et al., 2012). A PPI analysis assesses how functional connectivity between brain regions is altered in response to a specific state or context (here CTR; Gitelman et al., 2003). More specifically, we explored whether the brain region related to processing *"Functional Benefits"* (i.e., the ITG) and the brain region related to processing "*Imagination and Mental Stimulation*" (i.e., the DLPFC) interacted more with other brain regions in response to more successful commercials (i.e., with higher CTR). With this analysis, we aimed to provide more insights into the processes through which these particular functional and experiential elements drive ad effectiveness.

We estimated for each participant a first-level GLM with the following regressors: (1) a boxcar regressor with the onset times for each commercial parametrically modulated by its related CTR and convolved with the canonical HRF, constituting the psychological regressor; (2) a regressor with the deconvolved time series of the first eigenvariate of the BOLD signal in the seed brain region (i.e., ITG or DLPFC), constituting the physiological regressor; and (3) an interaction regressor (the PPI), representing the interaction between the psychological regressor and the physiological regressor. The GLMs also included six motion regressors, three extra nuisance regressors and constants as regressors of no interest. The seed brain regions were defined as the same two ROIs as described above. Group level analyses were performed by calculating one-sample t-statistics on the first-level contrasts of the interaction (the PPI) regressor.

First, we performed a PPI analysis to identify areas that exhibited context-dependent functional connectivity with the left ITG. We found that for more successful commercials, the ITG was more strongly connected to the left and right supramarginal gyri (SMG), the right DLPFC (i.e., precentral gyrus) and the left insula (see Table 4.6A and Figure 4.5A). Furthermore, results of the second PPI analysis indicated that the right DLPFC exhibited more functional connectivity with the left ITG, the amygdala, the right MTG, and the left

fusiform gyrus during exposure to more effective commercials (see Table 4.6B and Figure 4.5B).

Table 4.6. Psychophysiological Interactions

Region	Hemisphere	MNI Coordinates			Cluster Size	Z
		x	y	z	[k voxels]	
A) Seed Region: ITG						
Supramarginal Gyrus	R	66	-25	36	107	5.16*
DLPFC: Precentral Gyrus	R	48	-1	29	43	4.55
Insula	L	-42	-4	-4	11	3.64
Supramarginal Gyrus	L	-48	-25	29	15	3.34
B) Seed Region: DLPFC						
Inferior Occipital Gyrus ext. into Inferior Temporal Gyrus	L	-48	-70	-14	112	4.80*
Amygdala	R	24	-4	-14	43	4.63
Middle Temporal Gyrus	R	60	-58	-1	54	4.10*
Fusiform Gyrus	L	-33	-40	-27	17	3.80

Notes: Regions listed exceed threshold of $p < .001$ uncorrected, with at least 10 contiguous voxels. Regions denoted with asterisk exceeded threshold of $p < .05$ FWE corrected on the cluster-level. Z-values for each peak are given. Abbreviations: R = Right, L = Left, ITG = inferior temporal gyrus, DLPFC = dorsolateral prefrontal cortex. N = 24.

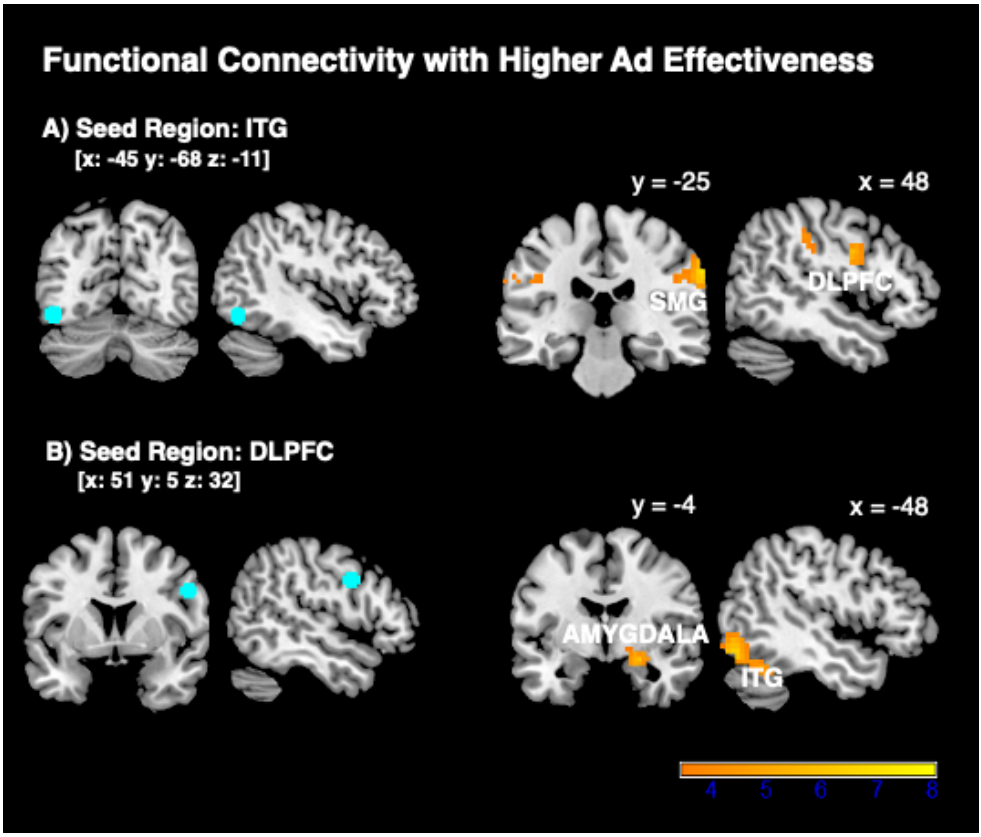

Figure 4.5. Results of psycho-physiological interactions. The higher the CTR, the more functional connectivity between A) seed region ITG (indicated in blue) and the supramarginal gyri (SMG) and the DLPFC; and B) seed region DLPFC (indicated in blue) and the amygdala and the ITG. Displayed brain activity exceeds threshold of $p < .001$ uncorrected, with at least 10 contiguous voxels. Color bar represents t-statistics. See Table 4.6 for more details not shown here.

4.5 Discussion

The main objective of this study was to explore the neural processes evoked by different executional elements in advertisements using fMRI methodology, and to demonstrate how these processes relate to out-of-sample advertising effectiveness. The unique set of eleven commercials for the same brand enabled us to investigate the influence of differences in ad appeal on neural responses and subsequent ad effectiveness, while keeping other factors (i.e., brand, product type, ad duration) constant.

Our findings reveal that ads demonstrating the functional benefits of the product (i.e., a focus on the advantages for the consumer), and appealing to imagination (i.e., thinking in a different, original and innovative way, approaching things from a new angle) were most effective here in stimulating click-through behavior. Ads successfully employing these functional and experiential executional elements more strongly engaged a particular combination of brain regions, including regions in the temporal cortex and the DLPFC. More specifically, the functional element ("*Functional Benefits*") was associated with responses in the temporal cortex, while the experiential element ("*Imagination and Mental Stimulation*") evoked neural responses in the DLPFC. Furthermore, we found the neural activity within these particular brain regions in response to viewing the television commercials to be significantly predictive of ad effectiveness in an independent sample of consumers, adding to previous findings in the decision neuroscience literature showing that neural responses in a limited number of subjects can be used to predict preferences of the population at large (e.g., Berns & Moore, 2011; Boksem & Smidts, 2015; Falk, Berkman, & Lieberman, 2012; Venkatraman et al., 2015).

Previous neuroimaging studies have demonstrated that the temporal cortex is involved in higher-level perceptual processes, such as object identification, recognition and interpretation (e.g., Bar et al., 2001). The temporal cortex thus plays an important role in rapidly identifying '*what*' things are, and constitutes an important hub in the so-called ventral stream, or the '*what pathway*', of visual processing (Goodale & Milder, 1992). More specifically, the left MTG has been found to be engaged when people identify objects that serve a specific purpose (tools; e.g., Johnson-Frey, 2004; Martin et al., 1996) and actions associated with the use of these objects (Damasio et al., 2001). In particular, the ventral and lateral temporal cortices are activated when people are asked

to answer questions on how to use tools and other objects, suggesting that these areas store information about specific object attributes and which actions may be performed when using these objects (Chao, Haxby, & Martin, 1999). Here, we found this area of the brain to be specifically associated with the degree to which references to functional benefits were present in the ads, suggesting that processes related to identifying or evaluating the potential use of a product are engaged when this functional element is present in the ad.

In addition, we show that more effective commercials were associated with increased functional connectivity between the left ITG and the supramarginal gyri. Previous research indicates that the supramarginal gyri play a central role in empathy (e.g., Lamm, Batson, & Decety, 2007) and perspective-taking abilities (e.g., during pain perception; Heijden et al., 2013). These results might indicate that for more successful commercials, participants were better able to take the perspective of the actors (i.e., demonstrating the advertised product), potentially leading to a more immersive experience of the ad.

In summary, given that we find regions in the temporal cortex to specifically respond to those commercials that convey information on the functional benefits of the advertised product, while activation in the ITG was also found to predict CTR, our results suggest that effective processing of information on the product itself, but also of how the product should be used may lead to increased success of the commercial at the population-level.

Our findings also demonstrate an important role for experiential elements in driving ad effectiveness in our set of commercials. We show that neural responses in the right DLPFC were particularly evoked by experiential elements in commercials that appeal to imagination and take a more original, innovative perspective, while increased activation of this region was also predictive of CTR. Previous research has shown that the DLPFC is associated with higher-level cognitive processes such as sustained attention and working memory, processes which are critical for enabling creative thought (for a review see Dietrich (2004)), such as insight problem solving ('aha!') or creating fluid analogies (e.g., Geake & Hansen, 2005).Ellamil et al. (2012) show the role of the DLPFC in creative evaluation as well, as participants showed higher DLPFC (including MFG and IFG) activations when evaluating creative ideas, and suggest that this executive brain region enables an analytic mode of information processing that facilitates evaluation of the utility of novel ideas. Hence, our results suggest that the more ads succeed in activating these

higher-order cognitive processes, subserved by the right DLPFC, the more successful these ads were in stimulating click-through behavior in our population sample.

In addition, we show that higher efficacy of the commercials was associated with increased functional connectivity between the right DLPFC and the amygdala. Notably, the amygdala is strongly associated with emotional processing, and has been shown to be involved in the processing of both negative and positive affect (Davis & Whalen, 2001). The involvement of the amygdala in processing more effective commercials is in line with the findings from the literature on the important role of feelings and emotions in effective advertising (e.g., Aaker, Stayman, & Hagerty, 1986; Pham, Geuens, & De Pelsmacker, 2013).

Taken together, these findings may suggest that this experiential ad element not only effectively stimulates higher-order cognitive thought processes, but also affective processes, potentially indicating higher levels of emotional engagement, which in turn is related to higher population-level ad effectiveness.

Finally, our results reveal that for more successful commercials, the regions engaged by the functional and experiential ad elements become more functionally connected with increasing ad effectiveness. That is, we found more functional connectivity between the brain regions activated by the functional appeal (i.e., ITG, MTG) and part of the regions activated by the experiential appeal (i.e., DLPFC). This might suggest that if these processes are successfully activated together by the ad, these brain regions also connect and interact with each other (i.e., forming a connected network), putatively integrating the processes engaged by the functional and experiential appeals, which in turn is related to higher ad effectiveness.

In summary, we aimed to provide insights into cognitive and emotional processes in response to advertisements that are typically difficult to access using other approaches. In a first attempt to explore the neural responses to different ad appeals, we dissociate brain regions responding to functional and experiential executional elements in ads, and show that not only co-activation of, but also interaction between, these brain regions were associated to higher ad effectiveness. This study contributes to the discussions in the existing literature on the processing of ad appeals by providing insights that generate

novel hypotheses. Our fMRI findings do not seem to support a simple cognitive / emotional framework in which functional executional elements target cognitions and experiential elements target affect, but instead suggest a more complex interplay of cognitive and emotional processes. Our findings suggest that a functional appeal engages rapid processes related to the recognition, identification and detection of relevant information from incoming visual input depicting benefits of the advertised product. However, in contrast to the results of Brakus, Schmitt, and Zhang (2014), we did not find evidence for any deliberative reasoning processes indicating more cognitive elaboration in response to this functional information. It could be that passively viewing television commercials does not necessarily involve reasoning processes *per se*, or that functional information is more anticipated when the advertised good is utilitarian and thereby does not call for further cognitive, effortful elaboration. These hypotheses should be further explored in future research.

Our findings do reveal higher-order cognitive processes to be engaged by the experiential appeal. Additionally, the neural correlates suggest engagement of emotional processes for more effective commercials. Taken together, these potential indicators of higher-order emotional engagement might support earlier research showing that more original ways to convey a message may draw more attention to the advertised brand (Pieters, Warlop, & Wedel, 2002). Also, as the commercials advertised a utilitarian product, experiential appeals to imagination could be more surprising here, and thereby draw more attention or generate cognitive elaboration. Moreover, our finding that higher-order processes are engaged by the experiential element seems to support the findings of Brakus, Schmitt, and Zhang (2014), suggesting that experiential elements can be processed less fluently. While they find less fluent processing to be negatively related to liking, we find the potentially more effortful processing of the experiential appeal to be related to higher ad efficacy.

Finally, we add novel insights to the literature by providing evidence that the processes evoked by different appeals can get integrated and in combination increase advertisement effectiveness.

Practitioners' interest in consumer neuroscience research has recently been increasing, and the number of specialized neuromarketing research companies involved in ad testing is growing (Plassmann, Ramsøy, &

Milosavljevic, 2012). Higher levels of activity in the brain regions involved in reward processing are typically perceived as indicators of ad efficacy, building upon previous research in decision neuroscience demonstrating that these reward-related regions of the brain (notably the ventral striatum and the (ventral) medial prefrontal cortex) are predictive of future choice (e.g., Falk, Berkman, & Lieberman, 2012; Knutson et al., 2007; Levy et al., 2011, Venkatraman et al., 2015). However, as this study illustrates, no single brain region is responsible for consumer choices, and responses to marketing efforts are likely to depend on an array of neurobiological processes. In particular, this will be the case for complex dynamic stimuli such as television commercials. A focused interest in these specific regions (e.g., by using only a priori defined ROIs) might therefore be limiting, as other informative (and predictive) brain activations could be overlooked. Our findings suggest that neural activity outside the reward-related areas can be predictive of advertising efficacy, and can be meaningful in understanding *why* a commercial is effective when related to specific advertising executional elements.

Moreover, our findings suggest that an appeal with both functional and experiential elements was most successful in engaging crucial processes related to click-through behavior and that also the interaction between these neural processes was related to higher ad efficacy. These insights support previous research suggesting that emotional content can be beneficial to any ad, independent of product category or level of involvement (Pham, Geuens, & De Pelsmacker, 2013).

In general, caution is required for the interpretation of neuroimaging findings if reverse inference is applied (Plassmann, Venkatraman, Huettel, & Yoon, 2015; Poldrack, 2006). Reverse inference can be defined as a form of reasoning by which the engagement of a cognitive process is inferred from the activation of a particular brain region. The deductive validity of such inferences can be limited, as a given brain region may be involved in multiple cognitive processes. Given the explorative nature of the current study, our interpretation of the findings should be treated as 'hypothesis-generating' rather than conclusive. Hence, strictly speaking, future theory-driven research is necessary to confirm whether our interpretations of the underlying psychological processes hold when tested with an experimental design that directly manipulates these predicted underlying processes.

In the present study, we used eleven commercials for the same, utilitarian, low-involvement product. For this particular set of commercials, we found the demonstration of its functional benefits, as well as an appeal to imagination to be effective in activating brain regions predictive of click-through behavior. However, it could be that in a set of commercials for another product, different functional or experiential elements could drive effectiveness. Future research should investigate whether similar or different brain regions are engaged for those functional or experiential executional elements that are relevant in ads for a different product. Moreover, it would be interesting to explore whether employing an ad appeal focusing on functional benefits and imagination would result in similar neural responses when a more hedonic or high-involvement product is advertised.

Chapter 5
General Discussion

The general aim of this dissertation was to apply fMRI methodology to study how contextual information can influence the desirability of anticipated outcomes and thereby influence common, everyday, (consumer) behaviors. Across three neuroimaging studies, I demonstrated how the brain processes different types of contextual information, and how these neural processes are subsequently related to observed decision behavior.

In the empirical chapters of this dissertation (Chapter 2, 3 and 4), I discussed each study in detail. In this final chapter, I will summarize the key findings, implications, challenges and limitations, and focus on the general theoretical and applied contributions of this dissertation research.

5.1 Summary and Key Insights

5.1.1 Chapter 2: Neural Responses to Reward Proximity

In this chapter, I examined how progress relative to an anticipated outcome is monitored in the brain, and how this in turn impacts fluctuations in motivation across the course of goal pursuit. Classic and modern behavioral research on goal pursuit have repeatedly demonstrated that as humans and other animals approach a desired end state, their efforts toward reaching that end state increase. Using fMRI, we addressed the open question as to how goal proximity is encoded in the human brain, in order to better understand this so-called 'goal gradient motivation'. A deeper understanding of these processes could help to increase motivation more effectively. In this experiment, participants worked through a series of sequential actions (i.e., collecting 'stamps') that led to an anticipated reward (i.e., a monetary prize), during which they could monitor their progress relative to this end-state. We used an MRI compatible handgrip to assess various measures of effort (most importantly, force production and reaction time) to infer participants' motivational state.

Our findings demonstrate that the brain continuously tracks progress relative to an anticipated reward. We find that regions that have been previously related to reward anticipation, most notably the ventral striatum and the rACC, are indeed more engaged as participants approach goal completion. These results suggest that proximity modulates the value representation of the outcome, encoded within the brain's reward system, driving the increase in motivation. Interestingly, similar regions have been found to track reward

proximity in animals (particularly the monkey's rACC), suggesting that there could be a shared, common neural mechanism monitoring reward proximity. Moreover, the findings show that there is a particular boost in motivation at the final step towards goal completion, which correlated with increased activity in the salience network (anterior insula and MCC/dACC).

In summary, these findings suggest that the brain focusses behavior as people are working through a fixed series of steps in order to achieve an outcome, as a function of relative proximity to this outcome. As such, our findings not only replicate the existing behavioral literature on goal gradient motivation, but also expand our understanding of this phenomenon by identifying its respective neural processes. These processes provide evidence for the hypothesis that the observed behavioral response to goal progress is driven by an increase in the *anticipated value* of the outcome - even if the *absolute value* of that outcome does not increase over time - and in addition is driven by an increase in salience of the final step towards goal completion.

Future research could build upon these findings by further examining how different brain regions identified in this study are functionally, and effectively, connected. Such evidence would further clarify if, and how, networks related to reward proximity (e.g., ventral striatum, rACC), correlate with (i.e., exhibit functional connectivity with) or exert influence over (i.e., show effective connectivity with) regions related to the salience network (e.g., anterior insula, dACC) and motor control (e.g., dorsal striatum, SMA) that together drive goal gradient motivation.

5.1.2 Chapter 3: Neural Mechanisms of Choice Diversification

In this chapter, which has been published in Frontiers in Neuroscience (Couwenberg et al., 2020), I examined how making multiple choices from a set impacts variety-seeking behavior. Previous behavioral research has shown that when asked to select several options at once, people tend to choose a greater diversity of items than when they are asked to make these selections one at a time. While this 'diversification bias' can have profound consequences on choice outcomes, little is known about the brain mechanisms that drive this phenomenon. We proposed that, as people make multiple selections from a menu of different options, the current state of their choice portfolio (i.e., the history of previously selected options) dynamically influences the utility of the remaining options in the choice set, represented

in the brain's valuation network. More specifically, we hypothesized that two different psychological mechanisms could independently drive diversification. People may diversify because (1) the utility of an option decreases when that option has been already selected ('satiation'), and/or (2) the utility of a non-selected option increases when alternative options have already been picked ('novelty-seeking'). We investigated how the neural valuation network might update the utility signal to produce these choice patterns, by scanning participants' brains using fMRI while they made a series of product choices.

Our behavioral data confirm that participants indeed diversify on the majority of their choice portfolios. The neural data provide evidence that these portfolio effects on choice are driven by valuation processes. That is, we find that activity in both the ventral striatum and the VMPFC was modulated by the context of previously selected options. More specifically, the findings show that, most prominently, activity in the ventral striatum decreased in response to options if these had been previously selected, aligning with the 'satiation' hypothesis. At the same time, we find an increase in activity, specifically in the VMPFC, in response to previously rejected options when other options have been selected in the meantime. This finding suggests that people have intrinsically greater value for different options as they are completing their choice portfolio, in line with the 'novelty-seeking' hypothesis. Thus, our results suggest that both the 'satiation' and 'novelty-seeking' mechanisms can drive diversification and are represented at the neural level by different regions within the brain's valuation network.

While this chapter provides novel insights into brain processes underlying diversification, some questions remain unanswered and would be interesting and meaningful to address in future studies. For example, it would be valuable to assess whether participants actually desired previously chosen options less or rather were explicitly looking to diversify their portfolio when they chose an alternative option. This would increase our confidence that the observed changes in the ventral striatum and VMPFC are indeed related to satiation and novelty-seeking. While our study provides some correlational evidence, future work could manipulate satiation or novelty-seeking motivations more directly (and separately) and investigate the respective causal impact on the identified processes and behaviors. For example, this could be done by having people consider either the negative impact of choosing consistently (likely promoting

satiation) or the positive impact of diversifying (likely promoting novelty-seeking) on their future consumption experience before making a choice.

Another potentially valuable methodology to test the discriminability of the two hypotheses is to apply a form of normalization (e.g., divisive normalization; Rangel & Clithero, 2012; Rigoli et al., 2016). That is, neural responses associated with a value could depend on its relative position in the overall distribution of values (e.g., unchosen options in a choice set). With normalization, one possibility is that a 'novel' choice option could actually reduce the value of all the other items, while satiation towards a previously chosen item could increase the value of the rest.

5.1.3 Chapter 4: Neural Responses to Ad Appeals

In this chapter, which has been published in the International Journal of Research in Marketing (Couwenberg et al., 2017), I explored the neural responses to different advertisement appeals in television commercials and test if these neural signals are related to the effectiveness of the commercial. Ads with a predominant 'functional' appeal typically convey a message that focuses on factual information to explain why the consumer should like and buy a product, for example references to the product's attributes, use, and performance, as well as the benefits and value that come with these features. In contrast, one of the key ideas of an 'experiential' advertising appeal is that value does not only reside in the advertised good and its utilitarian and functional benefits, but also in the emotional and experiential elements associated with the good, and in the (indirect) experience of it. Accordingly, experiential elements of an ad particularly evoke sensations, feelings, emotions, imaginations and behavioral responses. Prior attitudinal and behavioral research in marketing indicates that internal processes in response to ad appeals are important drivers of ad effectiveness. However, these 'internal processes' are typically measured by stated attitudes and may therefore be severely limited as they rely on people accurately describing their internal responses to dynamic stimuli. In this study, we aimed to build upon this extensive body of research by using fMRI, providing more immediate insights into the implicit mental processes associated with different executional elements. Comparing a unique set of different television commercials for the same brand enabled us to investigate the influence of differences in ad appeal, in terms of its functional and experiential elements, while keeping other factors (i.e., brand, product type, ad duration) constant.

We measured brain responses in a 'neural focus group' and ad effectiveness (i.e., click-through rate: CTR) in an independent sample of consumers.

Our findings revealed that ads demonstrating the functional benefits of the product, and additionally also appeal to one's imagination, were most effective in stimulating CTR. Moreover, functional elements evoked activity in the temporal cortex, suggesting that a functional appeal engages rapid processes related to the recognition, identification and detection of relevant information from incoming visual input depicting the benefits of the advertised product. Our findings also revealed the DLPFC to be engaged by the experiential appeal, suggesting higher-order cognitive processing. Through functional connectivity analyses, we further demonstrated engagement of the amygdala for more effective commercials, suggestive of emotional processing. Finally, we provided evidence that the neural processes evoked by these different appeals are functionally connected, and in combination predict advertisement effectiveness in the independent sample. In summary, our fMRI findings do not seem to support a simple cognitive / emotional framework as suggested in traditional marketing theory, in which functional executional elements target cognitions and experiential elements target affect, but instead suggest a more complex interplay of cognitive and emotional processes, thereby adding important nuance and detail to both the marketing and consumer neuroscience literature.

Given the exploratory nature of this study, our interpretation of the underlying processes should be treated as 'hypothesis-generating' rather than conclusive. Hence, strictly speaking, future theory-driven research is necessary to validate our interpretations with an experimental design that directly manipulates these predicted underlying processes. In addition, we used eleven commercials for the same, utilitarian, low-involvement product. It would be valuable if future studies in consumer neuroscience explore whether employing an ad appeal focusing on functional benefits and imagination would result in similar neural responses when a more hedonic or high-involvement product is advertised.

5.2 General Theoretical Contribution

In this dissertation, I have argued for the value of conducting neuroscientific research in examining how contextual information is integrated into decision-making processes, and how this information ultimately shapes behavior. I

explored how combining theory and methodology from psychology, marketing, and neuroscience can advance our understanding of three different phenomena in everyday consumer behavior that have been previously established in the lab and in the field. I addressed open questions regarding the neural processes that underlie these phenomena, with the goal of complementing existing research by taking a novel perspective and applying neuroimaging methodology. As such, a broader aim of this dissertation was to test the hypothesis that this type of interdisciplinary research can advance theories of consumer behavior.

All three empirical studies discussed in this dissertation contribute to existing literature, by demonstrating evidence of context dependent valuation processes that would not have been possible to obtain with attitudinal and behavioral methods alone. Generally, these findings demonstrate that neural processes in response to contextual information are often complex but, importantly, carry informative signals about subsequent decisions and behavior. Therefore, these studies do not only refine existing theories, but also show that there is opportunity for future research in this domain to continue to build upon these findings, to solve the identified challenges, and to test the new hypotheses that this research has generated.

Lastly, my dissertation highlights the need for scholars in consumer behavior, and psychologists more broadly, to consider extending their range of theories and methodologies to studying decision-making and related behavior. At the same time, it should encourage scholars in neuroscience to consider the wealth of literature in the behavioral disciplines, as these can provide relevant hypotheses and open questions. Overall, my research suggests that doing so may not only increase methodological rigor and confidence in our understanding of the drivers of the observed phenomena, but will also lead to a better exchange of scientific insights. I believe that this will help us reach our common goal, that is, to answer important questions about human behavior and decision-making more effectively.

5.3 Practical Applications of Insights

While optimizing the presentation and communication of products and services so that they are more compatible with consumer preferences is a fundamental goal for marketing professionals, understanding the drivers of behavior, facilitating choice processing, and guiding a menu of choice options

or other offerings is of relevance to a range of industries and professions. As such, the presented insights into the impact of contextual information on choice could be of value to marketers, user experience designers, or public policy makers in helping them achieve desired behavioral outcomes for their target audiences. In this section, I will outline some opportunities (and challenges) for the practical application of the findings discussed in this dissertation.

5.3.1 (Neuro)marketing

Chapter 4 demonstrates that neural responses to ads carry informative signals that are related to the general effectiveness of an ad. More specifically, we found that combining functional with experiential executional elements makes for a more effective ad appeal. Based on these insights, marketing professionals could consider including both elements in their ads, by not only clearly demonstrating the product benefits, but also by adopting a creative approach to trigger the consumer's imagination (which may be a necessary condition to get these benefits across most effectively).

Moreover, this research demonstrates the potential value for marketing professionals to test and analyze their creatives using neuroscientific methodology. Since the publication of the first consumer neuroscience studies around two decades ago, there have been numerous evaluations of the development of the field in general (e.g., Plassmann et al., 2015; Yoon et al., 2012; Smidts et al., 2014), the relevance of neuroscientific methods in the study of consumer behavior (Lee et al., 2017; Lim, 2018), and also of the ethical concerns related to these type of studies (e.g., Stanton, Sinnott-Armstrong & Huettel, 2017). In the meantime, interest in the utility of neuroscientific techniques for marketing practices has grown (see Smidts (2002) or Ariely & Berns (2010) for early perspectives, and Levallois et al. (2019) for a recent overview). This particular industry, termed 'neuromarketing', involves with the commercial use of neuroscientific theories and methods to gain consumer insights (e.g., Ramsøy, 2015; Lim, 2018). Insights from consumer neuroscience suggest there is potential for applications in market segmentation (Venkatraman et al., 2012), pricing (Karmarkar et al., 2015; Plassmann et al., 2008), product and brand development (Chan, Boksem & Smidts, 2018; Esch et al., 2012; Plassmann et al., 2012; Pozharliev et al., 2015; Reimann et al., 2012), brand information (McClure et al., 2004), package design (Reimann et al. 2010), and advertising (Chan et al., 2019; Doré et al., 2019; Eijlers, Smidts &

Boksem, 2019; Klucharev et al., 2008; Stallen et al., 2010). As such, neuromarketing companies have emerged that apply neuroscientific techniques with the goal to improve a variety of marketing efforts.

The growing body of research identifying neural signals predictive of choice, even across independent, large-scale samples of consumers (e.g., Barnett and Cerf, 2017; Boksem & Smidts, 2015; Chan, Boksem & Smidts, 2018; Falk, Berkman, & Lieberman, 2012; Genevsky & Knutson, 2015; Genevsky, Yoon & Knutson, 2017; Knutson et al., 2007; Levy et al., 2011, Venkatraman et al., 2015), suggest neuroscientific methodology could be a valuable tool to assess consumer preferences. It should be noted that a focused interest in specific regions identified in previous research (e.g., by using only a priori defined regions-of-interest) could be limiting if considered in isolation. As Chapter 4 in this dissertation also illustrates, it is unlikely that activity in pre-defined brain regions is indicative for (or predictive of) all consumer choices, as responses to different types of marketing efforts likely depend on an array of neurobiological processes. In particular, this will be the case for complex dynamic stimuli (such as television commercials). Moreover, caution is required for the interpretation of neuroimaging findings if reverse inference is applied (Poldrack, 2006). Reverse inference is reasoning by which the engagement of a cognitive process is inferred from the activation of a particular brain region. The deductive validity of such inferences can be limited, as a given brain region may be involved in multiple cognitive processes. Recent methodological advances in analyzing neuroimaging data open new possibilities that allow to move beyond single voxel activations in location-based, univariate approaches. For example, multivariate pattern analysis (MVPA; e.g. Haxby et al., 2014) focuses on finding activation patterns in a subset of voxels. By using machine learning and pattern similarity analysis, patterns of neural responses to consumer choice contexts can be extracted, analyzed and interpreted (see for example, Chan, Boksem & Smidts, 2018; Chan et al., 2020).

In sum, depending on the purpose of the marketing research, neuroscientific techniques could add value to conventional methods when interested in measuring implicit responses, if applied with scientific rigor and interpreted with caution (as with any other marketing research methodology).

5.3.2 User Experience Design

The findings discussed in this dissertation could also inform product design, with the goal of improving the general user experience and to ensure that users get most value from the product or service. In particular, insights into how contextual information can impact how attitudes are formed and decisions are made can be applied to copywriting and the design of user journeys and user interfaces. Designing the choice architecture of products or services more intentionally could help users better understand the product or service and, in turn, more effectively reach their goals. Here, I provide two specific examples of how our findings could inform design.

First, Chapter 2 shows that progress is continuously monitored by the brain to assess proximity to an anticipated outcome, and is used to regulate behavior to reach that outcome. This insight demonstrates the importance of explicit progress cues in any situation where maintaining engagement is challenging and users are likely to drop off. For example, progress bars could be helpful in multi-screen registration or onboarding flows for digital applications, new device set-up processes, or payment flows on e-commerce platforms. As our fMRI findings suggest that the *anticipated value* of the desired end state increases with proximity, it might also be useful to remind the user of *why* taking each step of the process – especially in the beginning, when anticipated value is relatively lower – is important in reaching that end state. Importantly, our neural research identified a special role for the 'final step', as the salience network in the brain is specifically engaged at the final step before goal completion (driving a final boost in motivation). This insight can be applied to motivate behavior, by clearly marking the final step in multi-step user flows, or by increasing the perceived marginal value of a single action by framing it as a more meaningful step towards goal completion (e.g., re-framing a call-to-action from "Next" to "Complete").

Second, our findings discussed in Chapter 3 (demonstrating that our previous choices influence subsequent choices) indicate how the choice architecture of e-commerce platforms could impact consumer choice. That is, this research suggests that making consumers' previous selections (for example, those from the current or from a previous shopping session) salient during the product selection process, could lead consumers to perceive their choice as a *portfolio choice*, and thus strongly impact their decisions. As our fMRI research shows, this could lead users to devalue already chosen items, and value new items

more, and therefore encourage diversification behavior. As such, the way e-commerce platforms design the moment of purchase can either stimulate or demotivate variety-seeking. Consumers might be more open to consider variety (e.g., a different type of fruit, or a different flavor of noodles) if they select more items within the same product category, and their selections are visible as they make their choices. Our neural findings show that (anticipated) satiation can also drive diversification in portfolio choices. When people are requested to make several choices at once for future consumption (e.g., monthly online meal plan selections for students), people might overestimate their level of satiation at the time of choice and select options they prefer less for the sake of variety. This could lead to a misalignment between the selected options and actual preferences at the time of consumption. As such, portfolio choices could lead to suboptimal experiences, and potentially (food) waste. To reduce (food) waste as a result of anticipated satiation, designers could reduce the perceived interdependence of future consumption occasions by designing the choice architecture in a way that encourages people to consider each consumption occasion in isolation, thereby motivating them to more consistently choose their preferred options.

5.3.3 Public Policymaking

Lastly, our findings could inform public policymaking. (Local) governments or other public organizations often wish to understand, predict and ultimately change behavior, or else provide services to stimulate specific behaviors. They could benefit from taking insights from this dissertation research to effectively design interventions to encourage desired behaviors (such as healthy eating, saving money, donating to charity) or discourage less desired behaviors (such as smoking, littering, food waste) in similar ways as described in the previous sections.

In general, understanding neural responses to informational cues have already been proven helpful in this domain. For example, neural activity has been found to predict behavior (change) in response to health communication interventions (e.g., Falk et al., 2011; 2015). From this research, future public campaigns could be assessed based on their likelihood of effectively transmitting these messages. Similarly, Genevsky, Yoon & Knutson (2017) demonstrated that neural responses in the ventral striatum could be used to forecast market-level crowdfunding outcomes. These neuroimaging insights and methods could be valuable in the design of more effective

campaigns to drive prosocial behaviors. Chapter 4 in this dissertation further suggests that public campaigns could potentially benefit from including both functional and experiential elements to encourage behaviors of interest. Our research suggests that emphasizing the benefits of the promoted behaviors, as well as stimulating the audience's imagination by approaching this message from a different, surprising angle could be effective at activating these behaviors.

Moreover, results of the study described in Chapter 2 (in combination with the findings of Cryder et al., 2013; and Touré-Tillery & Fishbach, 2017) suggest that people might be more likely to donate in later stages of approaching the campaign goal. That is, our fMRI findings support the hypothesis that the final step to goal completion might be perceived as more impactful, focusing people's attention and behavior. As such, people might feel that by donating at a later stage, they have more personal impact on the outcome. This highlights an opportunity to frame an individual donation in a way that emphasizes how it positively changes the campaign's proximity to the desired end-state, and thus increases the perceived marginal impact of the donation in reaching this end-state.

5.3.4 A Note on Ethics

I would like to conclude this section with a brief note on the importance of considering the ethics of implementing insights from this dissertation, and from the discussed (neuroscientific and behavioral) literature more generally, with the goal to encourage behavior change. As demonstrated in this dissertation research, (subtle) cues in our choice environment are monitored in our brain and can impact decision processes and outcomes significantly. As such, the status quo of how choice environments are designed is never 'neutral' and can move (inattentive) people in one way or another. The insights discussed in this dissertation can be applied to *intentionally* encourage a desired behavior (as described above). This practice could be potentially impactful, so it should be done with caution and care. I want to emphasize the importance of preserving agency and choice for people at all times, and of not using these insights to drive people into making decisions they didn't mean to, even if we believe the outcome is good for them. Practitioners should apply these insights not to make decisions for people, but instead to make it easier for people to make decisions and reach their goals, in a way that results in good outcomes for them, as judged by themselves. When

applying neuroscientific and behavioral insights, we should always seek to promote welfare, dignity, and autonomy in people (see also Sunstein, 2015).

5.4 Concluding Remark

Taking an interdisciplinary approach to study these common, everyday, phenomena in (consumer) behavior is both exciting and challenging at the same time. For example, similar concepts are often described and measured differently across the various academic disciplines, and maintaining ecological validity within the limitations of these type of experimental paradigms is not always straightforward. However, I believe that integrating neuroscience methodology in the study of these context-dependent decision-making processes is essential to validate conclusions derived from behavioral and attitudinal methods, to challenge common assumptions, to generate new hypotheses, and ultimately to get a more comprehensive view of how our behavior is regulated, and our decisions are shaped.

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Summary

What makes an anticipated outcome more desirable to people? While an outcome can be evaluated in absolute terms (for example, the price of a bottle of wine), we often instead use contextual information as reference points to determine the relative desirability of an outcome (for example, comparing its price to the price of the other bottles of wine on the menu). That is, informative and circumstantial cues can strongly impact our attitudes and behavior toward an outcome, even if this information is not directly related to the outcome itself. The aim of this dissertation is to take an interdisciplinary approach to study how different types of contextual information can increase the desirability of anticipated outcomes and thereby influence common, everyday, (consumer) behaviors.

As measuring complex and implicit decision-making processes at the time of choice can be challenging, neuroscientific methodology can provide valuable insights. Across three empirical chapters, the general problem of how the brain evaluates contextual information prior to deciding on a subsequent course of action is addressed by combining knowledge and methodology from marketing, psychology and neuroscience. In particular, behavioral tasks are combined with functional magnetic resonance imaging (fMRI) methodology.

The first chapter examines the impact of context on fluctuations in motivation across the course of goal pursuit and, specifically, how associated progress cues are monitored in the brain. Prior behavioral and field research on goal pursuit has demonstrated that as humans (and other animals) approach a desired outcome, their efforts toward reaching that outcome increase ('goal gradient motivation'). In my experiment, participants worked through a series of sequential actions (collecting stamps on a stamp card, comparable to a loyalty card) that led to a reward (a monetary prize), during which they could

monitor their progress towards this reward. We used a handgrip to measure effort (i.e., a combination of force and reaction time) to infer participants' motivational state. The behavioral data revealed an increase in motivation as participants approach the desired outcome. The neuroimaging data showed that progress relative to this outcome is continuously monitored in the brain's reward and salience networks, and, importantly, is used to regulate subsequent effort production. These results suggest that reward proximity modulates the anticipated value of the reward, driving the observed increase in motivation towards the end.

The second chapter examines how the context of one's previous selections from a menu of options impacts decision-making. Prior behavioral and field research has shown that when asked to select several options from a menu at once, people tend to choose a greater diversity of items than when they are asked to make these selections one at a time ('diversification bias'). This choice pattern was investigated by scanning participants' brains while they made multiple selections from a menu of product options (for example, picking 3 yogurts from a menu of 5 different flavors). The choice data showed that participants diversified the majority of their choice portfolios. The neuroimaging data further revealed that previously selected options dynamically modulated activity in the brain's valuation system in response to options under evaluation, and suggest that people diversify because (1) the value of an option decreases when that option has been already selected before ('satiation'), and (2) the value of a non-selected option increases when alternative options have already been picked ('novelty-seeking').

The third chapter explores neural responses to different ways of framing the value of a product in television commercials (ad appeals), and examines if these neural responses are related to the effectiveness of the commercial. Using a set of different television commercials for the same brand, the influence of differences in ad appeal (in terms of its functional and experiential elements) on brain responses was investigated in a 'neural focus group', while ad effectiveness (click-through rate) was measured in an independent sample of consumers. Findings revealed that ads demonstrating the functional benefits of the product, and also appeal to one's imagination, were most effective in stimulating click-through. The neuroimaging data showed that functional and experiential executional elements engaged different brain regions, associated with both cognitive and emotional

processes, and the extent to which these particular brain regions engaged and interacted, was associated with higher ad effectiveness.

In sum, this dissertation demonstrates how the brain processes contextual information, and how these neural processes are subsequently related to common, everyday, (consumer) behaviors. The findings of this dissertation extend existing behavioral research by taking an interdisciplinary approach. A better understanding of these neural processes can help to generate new ideas on how to design choice environments more intentionally. Relevant areas to apply these insights could be found in marketing, product design or public policy aimed at promoting behavioral change.

Samenvatting

Wat maakt een bepaalde keuzeoptie meer of minder aantrekkelijk? Om dit te bepalen evalueren we soms de 'absolute waarde' van een keuzeoptie (zoals de prijs van een fles wijn), maar vaak gebruiken we referentiepunten in onze omgeving om de 'relatieve waarde' van een keuze te evalueren (bijvoorbeeld door de prijs te vergelijken met de prijs van de andere wijnen op de wijnkaart). Deze contextuele informatie in onze omgeving kan onze preferenties en keuzegedrag sterk beïnvloeden, zelfs indien deze informatie niet direct relevant is voor de keuze. In dit proefschrift wordt ingegaan op de rol van contextuele informatie in het keuzeproces, om beter te begrijpen hoe dit alledaags consumentengedrag beïnvloedt.

Aangezien impliciete keuzeprocessen vaak complex en moeilijk te meten zijn, kunnen neurowetenschappelijke methoden waardevolle inzichten bieden. In dit proefschrift worden kennis en methoden gecombineerd uit marketing, psychologie en neurowetenschappen om te onderzoeken hoe contextuele informatie verwerkt wordt in het brein. In het bijzonder wordt er gebruik gemaakt van *functional magnetic resonance imaging,* ofwel fMRI.

Het eerste hoofdstuk richt zich op de invloed van contextuele informatie op iemands motivatie om een doel te bereiken, en met name hoe informatie over de voortgang in het bereiken van dat doel wordt verwerkt door het brein. Eerder onderzoek laat zien dat wanneer mensen (en andere dieren) dichter bij het behalen van een doel komen, ze meer gemotiveerd raken en meer moeite doen om dat doel ook daadwerkelijk te bereiken (denk bijvoorbeeld aan een eindsprint in een hardloopwedstrijd). In het experiment deden proefpersonen een gedragstaak waarbij ze stempels konden behalen op een stempelkaart om daarmee een beloning te verdienen. Gedurende deze taak konden proefpersonen hun voortgang ten opzichte van deze beloning monitoren. In

dit experiment werd een handdynamometer gebruikt om motivatie te meten (motivatie is hierbij bepaald door de combinatie van knijpkracht en snelheid van knijpen). De resultaten laten zien dat motivatie inderdaad sterk toeneemt wanneer men dichterbij de beloning komt, en dat informatie over de voortgang continu wordt gemonitord in zowel het belonings- als het saliencenetwerk in het brein. Deze breinprocessen reguleren aandacht en gedrag. De resultaten laten zien dat de afstand tot een beloning de 'relatieve waarde' van de beloning beïnvloedt, wat de motivatie een *boost* geeft als deze afstand kleiner wordt.

Het tweede hoofdstuk richt zich op de vraag hoe eerder gemaakte keuzes huidige beslissingen beïnvloeden. Eerder onderzoek laat zien dat wanneer mensen meerdere opties uit een assortiment kunnen selecteren (bijvoorbeeld 7 mueslirepen voor de komende week) ze meer variatie kiezen (bijvoorbeeld verschillende smaken) dan wanneer ze telkens één keuze maken per keer (bijvoorbeeld elke dag van de week 1 mueslireep). In dit onderzoek werd het breinmechanisme van dit keuzepatroon onderzocht terwijl proefpersonen meerdere keuzes maakten uit een assortiment. De resultaten laten zien dat het beloningsnetwerk in het brein meer of minder actief is afhankelijk van eerder gemaakte keuzes, en suggereren dat mensen diversificeren omdat (1) de subjectieve waarde van een keuzeoptie minder wordt als die optie al eerder is gekozen ('verzadiging'), en (2) de waarde van nog *niet* gekozen keuzeopties toeneemt als andere keuzeopties al zijn gekozen ('variatie-zoekend gedrag').

Het derde hoofdstuk onderzoekt hoe het brein reageert op twee verschillende manieren om een product aan te prijzen in televisiecommercials, en hoe deze breinprocessen vervolgens gerelateerd zijn aan de effectiviteit van de commercial. Bij een relatief kleine groep consumenten in de scanner (een 'neuro-focusgroep') werd de impact van functionele en experiëntiele elementen van televisiecommercials op het brein onderzocht, terwijl de effectiviteit (kliks naar de website van het product) werd onderzocht binnen een grote, onafhankelijke groep consumenten. De resultaten laten zien dat de meest effectieve commercials zowel de functionele voordelen van het product laten zien, als ook de verbeelding stimuleren. De breindata laat zien dat deze functionele en experiëntiele elementen verschillende breingebieden activeren die geassocieerd zijn met zowel cognitieve als emotionele processen, en dat de mate waarin deze gebieden juist *samen* actief zijn gerelateerd is aan een hogere effectiviteit van de reclame.

Dit proefschrift biedt nieuwe inzichten in hoe het brein contextuele informatie verwerkt, en hoe deze breinprocessen vervolgens alledaags consumentengedrag reguleren. Een beter begrip van deze breinprocessen helpt om de keuzeomgeving effectiever te ontwerpen. Een relevante toepassing van deze inzichten is mogelijk te vinden in marketing, product design of overheidsbeleid gericht op gedragsverandering.

About the Author

Linda Couwenberg (1988) obtained her Bachelor of Science (2010) and Master of Science (2012, *cum laude*) in Psychology from Leiden University. In 2012, she started her PhD in Consumer Behavior and Decision Neuroscience under the supervision of Prof. Ale Smidts and Dr. Maarten Boksem at the Rotterdam School of Management, Erasmus University. The interdisciplinary nature of her research involved supervision by Prof. Alan Sanfey at the Donders Institute.

Her doctoral research has been published in the International Journal of Research in Marketing and Frontiers in Neuroscience, and has been featured in (inter)national media. She has presented her work at numerous academic conferences (including the annual meetings of the Society for Neuroeconomics, the Association for Consumer Research and the Society for Consumer Psychology) and to various non-academic professional audiences. In 2016, Linda was a visiting research scholar at Stanford Graduate School of Business. During her PhD studies, she started a think-tank (now THRIVE PhD Academy) together with fellow PhD students with the goal to connect researchers with public policy makers and entrepreneurs to boost their societal impact.

In August 2017, she moved to California to pursue her passion for applying consumer decision-making insights and methods by working as a User Experience Researcher at Idean in Palo Alto. In October 2018, she started her current job as Behavioral Scientist at Google in London.

Academic Portfolio

Education

MSc (Research) in Psychology, 2010 – 2012 *(cum laude)*
Leiden University

BSc in Psychology, 2006 – 2010
Leiden University

Publications

Couwenberg, L. E., Boksem, M. A. S., Sanfey, A. G., & Smidts, A. (2020). Neural Mechanisms of Choice Diversification. *Frontiers in Neuroscience,* 14:502. https://doi.org/10.3389/fnins.2020.00502

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Couwenberg, Linda, Maarten Boksem, Roeland Dietvorst, Loek Worm, Willem Verbeke, and Ale Smidts (2016),"Neural Responses to Functional and Experiential Ad Appeals: Explaining Ad Effectiveness", in NA - *Advances in Consumer Research*, Volume 44, eds. Page Moreau and Stefano Puntoni, Duluth, MN: Association for Consumer Research, Pages: 82-87.

Working Papers

Couwenberg, L.E., Smidts, A., Sanfey, A.G., & Boksem, M.A.S. "Neural Responses to Reward Proximity." Manuscript in preparation for submission.

Research Visit

Stanford University, Graduate School of Business (Marketing), 2016

Conference Presentations

Couwenberg, L.E. et al. "Neural Mechanisms Underlying Diversification in Consumer Choice"

- Oral Presentation at Society for Consumer Psychology, San Francisco, USA (2017; *co-chair of special session*)
- Oral Presentation at Annual Symposium on Decision Neuroscience, Stanford GSB, USA (2017)
- Oral Presentation at Annual Meeting of the Society for Neuroeconomics, Berlin, Germany (2016)
- Poster Presentation at Consumer Neuroscience Symposium, Berlin, Germany (2016)

Couwenberg, L.E. et al. "Neural Responses to Functional and Experiential Ad Appeals: Explaining Ad Effectiveness"

- Oral Presentation at Association for Consumer Research, Berlin, Germany (2016; *co-chair of special session*)
- Oral Presentation at Annual Symposium on Decision Neuroscience, Stanford GSB, USA (2014)
- Poster Presentation at Consumer Neuroscience Symposium, Miami, USA (2014)
- Poster Presentation at Annual Meeting of the Society for Neuroeconomics, Miami, Florida, USA (2014)
- Poster Presentation at Consumer Neuroscience Symposium, Lausanne, Switzerland (2013)
- Poster Presentation at Annual Meeting of the Society for Neuroeconomics, Lausanne, Switzerland (2013)

Doctoral Teaching Experience

Lecturer, Bachelor Course 'Neuroeconomics: How the brain decides', Rotterdam School of Management, Erasmus University (2014, 2015, 2016)

Coordinator and Academic Instructor of Marketing Internships, Bachelor (International) Business Administration, Rotterdam School of Management, Erasmus University (2015, 2016, 2017)

Instructor Course 'Research Training and Bachelor Thesis' and Bachelor Thesis Supervision, Bachelor Business Administration, Rotterdam School of Management, Erasmus University (2014, 2015)

Selected Doctoral Coursework

- Topics in Consumer Behavior: Advances in Consumer Neuroscience, *Erasmus Research Institute of Management*
- Multi-level Analysis, *Erasmus Research Institute of Management*
- Data-analysis with R, *Erasmus Research Institute of Management*
- Neuroanatomy*, Donders Graduate School for Cognitive Neuroscience*
- Neuroimaging I, *Donders Centre for Cognitive Neuroimaging*
- The Toolkit of Cognitive Neuroscience: Advanced Course in Functional Neuroimaging Data Analysis*, Donders Centre for Cognitive Neuroimaging*
- The Toolkit of Cognitive Neuroscience: Advanced Topics in MR Imaging of the Brain, *Donders Centre for Cognitive Neuroimaging*
- Consumer Behavior, *Tilburg University*
- Eye-tracking for Visual Marketing, *HEC Paris*

Selected Other Publications

Couwenberg, L.E. (2017). Effective ads: New technology answers old questions. *RSM Discovery - Management Knowledge, 30*(2), 5-7.

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https://repub.eur.nl/pub/94976

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EPS-2018-447-ORG, https://repub.eur.nl/pub/105243

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Promotors: Prof. S. Puntoni & Prof. S.T.L.R. Sweldens, EPS-2017-425-MKT,
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People often use contextual information as reference points to determine the desirability of an outcome. These contextual cues can strongly impact our attitudes and behavior toward an outcome, even if this information is not directly related to the outcome itself. This dissertation takes an interdisciplinary approach to study how different types of contextual information can increase the desirability of anticipated outcomes and thereby influence common, everyday, (consumer) behaviors. As measuring implicit decision-making processes can be challenging, neuroscientific methodology can provide valuable insights. Across three empirical chapters, this research examines how the brain evaluates contextual information prior to deciding on a subsequent course of action, by combining theory and methodology from consumer behavior and neuroscience. Specifically, behavioral tasks are combined with functional magnetic resonance imaging (fMRI) methodology to study the neural processes underlying goal-directed behavior, the neural mechanisms of variety seeking in a consumer choice context, and the neural responses to ad appeals. This dissertation demonstrates how an interdisciplinary research approach can facilitate theory development and shape models of consumer decision-making. Ideas for the application of insights to marketing, user experience design, and public policy are discussed.

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