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Self-control and the urge to eat:
coping strategies in an obesogenic environment

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<th>Abbreviation</th>
<th>Description</th>
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<tbody>
<tr>
<td>ACC</td>
<td>Anterior cingulate cortex</td>
</tr>
<tr>
<td>BAS</td>
<td>Behavioral Activation/Approach System</td>
</tr>
<tr>
<td>BIS</td>
<td>Behavioral Inhibition System</td>
</tr>
<tr>
<td>BMI</td>
<td>Body Mass Index</td>
</tr>
<tr>
<td>CAPS</td>
<td>Cognitive affective processing model of self-regulation</td>
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<tr>
<td>DEBQ</td>
<td>Dutch Eating Behavior Questionnaire</td>
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<tr>
<td>EEG</td>
<td>Electroencephalography</td>
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<tr>
<td>ERN</td>
<td>Error-related negativity</td>
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<tr>
<td>ERP</td>
<td>Event-related potential</td>
</tr>
<tr>
<td>ERP</td>
<td>Exposure with response prevention</td>
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<tr>
<td>fMRI</td>
<td>Functional magnetic resonance imaging</td>
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<tr>
<td>HRV</td>
<td>Heart rate variability</td>
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<tr>
<td>LPFC</td>
<td>Lateral prefrontal cortex</td>
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<tr>
<td>OECD</td>
<td>Organization for Economic Cooperation and Development</td>
</tr>
<tr>
<td>PFC</td>
<td>Prefrontal cortex</td>
</tr>
<tr>
<td>RS</td>
<td>Restraint Scale</td>
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<tr>
<td>TFEQ</td>
<td>Three Factor Eating Questionnaire</td>
</tr>
<tr>
<td>TOTE</td>
<td>Test-operate-test-exit</td>
</tr>
<tr>
<td>VMPFC</td>
<td>Ventromedial prefrontal cortex</td>
</tr>
<tr>
<td>VTA</td>
<td>Ventral tegmental area</td>
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1 Introduction.

Living in the developed world is often compared to living in a world of plenty [Polivy and Herman, 2010]. On the upside food insecurity seems to be no longer an issue but on the downside new challenges have emerged.

Above all overeating and obesity are growing problems especially in industrialized countries. Obesity is at the root of many medical conditions like cardiovascular disease, diabetes mellitus or cancer [Biesalski and Grimm, 2007; WHO, 2013].

Moreover, it is considered to be a huge burden for society in terms of reduced productivity and increased health care costs [Bublitz et al., 2010; Herman and Polivy, 2011]. Latest statistical reports show that more than fifty percent of all adults in OECD states can be classified as being overweight and over eighteen percent even as obese [OECD, 2013]. However, prevalence of obesity fluctuates strongly across different OECD nations. For example in the USA thirty-three percent of all men and thirty-five percent of all women are obese and obesity rates are still increasing [Ogden et al., 2007; Barry et al., 2009]. Additionally it has been estimated that up to seventeen percent of all children in the USA are obese and percentages are quickly rising as well [Ogden et al., 2010; Gauthier and Krajicek, 2013].

The search for the origins of obesity has been proven to be very difficult due to its complex etiology but many authors conclude that the increasing prevalence of overweight is at least partly the result of environmental alterations within the last decades [Hill and Peters, 1998; Herman and Polivy, 2008; Vartanian et al., 2008; Ogden, 2011]. Such changes can be seen in the form of increasing urbanization, developments in motorized transports and overall decreases in physical labor [Hill and Peters, 1998; Ogden, 2011; Gauthier and Krajicek, 2013; WHO, 2013].

Together with constant improvements in technology [Hill and Peters, 1998] these are only a few factors which contribute to a sedentary lifestyle and therefore to an environment often branded as “obesogenic” [Swinburn et al., 1999] or even “toxic” [Brownell and Horgen, 2004; Vartanian et al., 2008]. The multifaceted and complex concept of ”obesogenic” includes economic and political as well as familial and individual features [Swinburn et al., 1999; Gauthier and Krajicek, 2013]. It basically contains the totality of all possible impacts of the external world on stimulating overeating and therefore obesity [Swinburn et al., 1999; Gauthier and Krajicek, 2013].
By contrast some authors use the term “toxic” to highlight the excess of food and especially emphasize the role of the food industry in the development of the obesity epidemic [Brownell and Horgen, 2004; Vartanian et al., 2008; Polivy and Herman, 2010]. In this context the obesogenic environment is essentially described by the immense exposure to low-priced but particularly palatable foods which are also high in calories [Lieberman, 2006; Nederkoorn et al., 2006a; Forman et al., 2007; Nederkoorn et al., 2010; De Vet et al., 2013].

Moreover it has been hypothesized that not only the easy availability of such hyper-palatable foods but also their enhanced visualization in the media (e.g. television) [Lieberman, 2006] along with larger servings and a greater dietary variety add to the rising prevalence of obesity [Hill and Peters, 1998; Wansink, 2004].

It has been proposed that these cues are able to offset homeostatic eating control-signals by generating an intense urge for such highly palatable foods [Burton et al., 2007; Christensen, 2007; Zheng et al., 2009]. Such desires are often described as food cravings and are generally linked to a greater intake [Bobroff and Kissileff, 1986; Wansink, 2004].

Despite the fact that estimates regarding prevalence of cravings seem to be unstable [Christensen, 2007], the kind of food is very consistent. Most individuals seem to crave foods with high sugar and fat contents like ice-cream or chocolate [Gendall et al., 1997; Christensen and Pettijohn, 2001; Christensen, 2007].

Although food cravings are common [Christensen, 2007] and not specifically pathological [Alberts et al., 2010] there is evidence that they can lead to binge-eating, bulimia nervosa, overeating and therefore obesity and are also linked to depression, guilt and compromised cognitive abilities [Gendall et al., 1998; Cepeda-Benito et al., 2003; Tiggemann and Kemps, 2005; Burton et al., 2007; Alberts et al., 2010; Jáuregui-Lobera et al., 2012].

So while it is not surprising that it has become more and more difficult to cope with those urges to (over)eat, there is the question why the omnipresence of food-cues does not affect all people in the same way.

**In plain words: why are not all people obese or at least overweight?**
After all, being healthy is commonly seen as important and desirable among many people and most certainly a lot of them indeed want to change their lifestyle [de Ridder and de Wit, 2008]. For example they intend to stop drinking alcohol, eat healthier, lose weight or just exercise more [de Ridder and de Wit, 2008]. Still many attempts to do so fail essentially because it is often a greater challenge to change an undesired habit than to uphold a good one [de Ridder and de Wit, 2008].

To put it simply: Doing something that is good for yourself does not necessarily mean that it is easy too. With regards to the initial question, why some people are overweight and some are not, it would be therefore better to ask:

**Why are some people able to control themselves, while others are not?**

The difficulty of being in “control” is not exclusively a matter of being able to withstand food cravings or to fight the urge to (over)eat. It concerns everyone who has ever encountered temptation, procrastination, addiction [McGonigal, 2011] or just struggled with the difficulties of bringing one’s behavior into line with certain principles, beliefs or long-term objectives [Baumeister et al., 2007].

In terms of eating behavior there are some people who are able to use their cognitive capacities to restrict their food intake even in tempting situations, while others certainly try to regulate their eating behavior but eventually fail [Bublitz et al., 2010; Johnson et al., 2012]. Regardless of whether people are successful or not they have all one thing in common: they rely on self-control to combat the urge to eat [Baumeister et al., 2007].

While in many domains high self-control is usually seen as a desirable characteristic and is associated with a wide range of benefits including higher academic success, less anxiety, less alcoholism or depression [Baumeister and Alquist, 2009] it is still controversial when it comes to eating behavior and weight control [Johnson et al., 2012].

This skepticism is largely based on many studies showing that people who apply willpower to restrict their dietary intake will fail [Johnson et al., 2012].
Such failures of self-control can lead to counter-regulation effects, decreases in satiety signaling and ultimately lead to disinhibited eating and obesity [Herman and Mack, 1975; Johnson et al., 2012; Hofmann et al., 2013].

Although some individuals seem to be caught in this restrained eating cycle certainly not all dieters break down when exerting self-control [Bublitz et al., 2010; Johnson et al., 2012].

In chapter 2.1 of this thesis both philosophical and psychological theories as well as common measures of self-control will be discussed. In addition impulsiveness as the counterpart to good self-control will be further elaborated.

Chapters 2.2 and 2.3 will offer a discussion of the neurological correlates of self-control together with a review of the latest empirical evidence of possible beneficial effects of high self-control primarily in the eating domain.

Chapter 2.4 will introduce self-regulation models and theories in the context of (over)eating with particular focus on the role of the obesogenic environment. Additionally an overview of recent neuropsychological explanations why self-control fails, particularly in the presence of food cues, will be presented.

While chapter 2.5 discusses common strategies people use to cope with the urge to eat when tempted with palatable foods, in chapter 2.6 strategies to prevent self-control failure will be critically reviewed in the context of the strength/resource model of self-control.

This will serve as a transition to the empirical part of this thesis, which will be further elaborated in chapter 2.7.
2 Theoretical background.

2.1 Towards a definition of self-control.

2.1.1 Philosophical and psychological aspects.

The questions about what influences human behavior in general and, to be more specific, why some people are able to control themselves while others fail are very old [Hofmann et al., 2011]. Considering that humans are actually capable of thinking and behaving in rational ways, even ancient Greek philosophers wondered why people would ever act and behave against their better judgments [Strack and Deutsch, 2004; Hofmann et al., 2011].

For example, Aristotle addressed this issue in book VII.1-11 of the Nicomachean Ethics by defining two character traits which focus on the conflict between passion and reason namely enkrateia and akrasia [Kraut, 2001; Hofmann et al., 2011; Uebersax, 2014]. Enkrateia literally means “mastery” and can also be defined as effective self-control or self-governance. Akrasia on the other hand stands for the exact opposite and is explained as the “weakness of will” [Schacter et al., 2009; Uebersax, 2014]. So in Aristotle’s opinion both the enkratic and the akratic person would experience urges and feelings, which are contradictory to any reason, but only the akratic individual acts upon them [Kraut, 2001].

In terms of psychological research Williams James was one of the first who examined the concept of self-control by dissociating different kinds of human will. In his research “Principles of Psychology” he defined the “explosive will” as one part of the so called “unhealthy will”. The explosive will was characterized by strong urges, high disinhibition and therefore low self-control [Hofmann et al., 2011].

The core principles of controlling the self can also be traced back to Sigmund Freud and his famous paper “The Ego and the Id” [Freud, 1962; Carver, 2005]. In his “psychoanalytic theory of personality” he defined three different components of the human psyche: the id, the ego and the so called superego. The id (or it) is constantly seeking for instant satisfaction of all urges, is already present when someone is born and
works in a totally unconscious way. The id produces impulses and this process was described as the “pleasure principle”. Since such a behavior would be publicly intolerable, the “ego” is necessary to restrain the impulses generated by the “id” and is steered by the “reality principle” which mediates between the inner urges and demands of reality. The last factor is the “superego” which consists of all the learned morals, values and social norms. The ego has to mediate between the desires of the id and the ideals provided by the superego [Freud, 1962; Carver, 2005; Cherry, 2014]. Freud characterized the ability of the ego to deal with those forces as “ego-strength” [Cherry, 2014], which is very similar to current notions of self-control [Baumeister et al., 1998].

Carver and Scheier picked up the idea of ego-strength and created with the “Cybernetic Control Theory” one of the most fundamental models of self-control so far [Carver, 1979; Carver and Scheier, 1981]. It describes self-control in the context of feedback or “TOTE” loops [Carver and Scheier, 2001]. The acronym “TOTE” stands for “test-operate-test-exit”, which means that people apply self-control by comparing their present status to inner principles or norms (test) [de Ridder and de Wit, 2008; Vohs and Baumeister, 2011]. As soon as their monitoring process notices any kind of irregularity the operating process takes over, tries to decrease it (operate) and evaluate the outcome again (test). If the process was successful the process of controlling is finished (exit) [de Ridder and de Wit, 2008; Vohs and Baumeister, 2011]. The concept of such dynamic feedback loops simply describes that creating goals and attaining to them is essential in the process of self-regulation or self-control [Carver and Scheier, 2001; de Ridder and de Wit, 2008].

In other words, one of the basic properties of self-control is to set goals and to come up with successful strategies to accomplish them [de Ridder and de Wit, 2008]. This means that the self has to be seen as the “active agent” or the “decision-maker” [de Ridder and de Wit, 2008] who regulates the own behavior in a conscious and deliberate way and thereby exerts volition over the environment [Baumeister et al., 1998; de Ridder and de Wit, 2008; Vohs and Baumeister, 2011].
Besides the “Cybernetic Control Theory” many other theories of self-control have emerged over the years, but only some of those approaches have been applied to explain problems of self-regulation in health or eating behavior [Hofmann et al., 2011].

One important example would be the hot and cool system within the “cognitive affective processing model of self-regulation” (CAPS) by Walter Mischel [Mischel and Ayduk, 2004; Vohs and Baumeister, 2011]. This model is based on the delay of gratification paradigm which is used to investigate the capability to withstand an instant reward in order to get a bigger one at a later date [Mischel et al., 2011]. This leads to a conflict situation between the desire to take the smaller but accessible reward and to wait for the greater and more attractive alternative [Mischel et al., 1989; Vohs and Baumeister, 2011].

Another milestone in the research of self-control theory would be the strength/resource model created by Roy Baumeister, who compares self-control strength to muscular strength. In this notion self-control requires a limited and unknown resource which can be exhausted by resisting temptations and trying to stay in control [Baumeister et al., 2000; Baumeister et al., 2007].

Some researchers also equate self-control with conscientiousness, which is a group of personality traits containing responsibility, orderliness and diligence [Baumeister and Alquist, 2009; Hoyle, 2009; Duckworth, 2011; Moffitt et al., 2011]. So highly conscientious individuals are more self-confident, organized and controlled than people low in conscientiousness, who are generally characterized by being less self-disciplined and more impulsive [Hoyle, 2009].

Those authors consider self-control as the conscious and burdensome part of a broader construct named self-regulation [Baumeister et al., 2007; Baumeister and Alquist, 2009]. In their point of view self-regulation also includes procedures on a nonconscious level [de Ridder and de Wit, 2008; Baumeister and Alquist, 2009].

Although in this thesis self-control and self-regulation are used interchangeably, the inconsistent terminology alone outlines how challenging it is to assess the current literature.
Nevertheless one mutual characteristic of all those different conceptualizations of self-control is that it is needed to overrule or restrain immediate and automatic impulses or temptations, to alter thoughts and actions and basically to change “the self by the self” [Vohs and Baumeister, 2011] in order to accomplish an end result (e.g. a long-term goal), that would not happen in any other way [Baumeister et al., 2007; de Ridder and de Wit, 2008; Baumeister and Alquist, 2009; Vohs and Baumeister, 2011].

It is also necessary to emphasize that self-control is an essential part of human existence because people constantly rely on it in various situations every day [Baumeister et al., 2007; de Ridder and de Wit, 2008]. For example they need to control themselves to tolerate frustration at work or in relationships, not to act violently towards others, not to use inappropriate language, not to buy items they desire or simply not to eat or drink whatever they momentarily crave for [Baumeister et al., 2007; Baumeister and Alquist, 2009].

One of the basic human needs is to live in harmony with the surroundings in order to ensure a safe existing and to accomplish long-term wishes and goals [Baumeister and Alquist, 2009]. To attain this kind of harmony people always try to alter their surroundings, but in many cases it is impossible to modify the environment and so the only way is to alter the self [Baumeister and Alquist, 2009].

Moreover some authors also link self-control to the common view of free will [Baumeister, 2008]. This seems paradox at first because restraining of urges and immediate desires is basically a self-denying behavior [Baumeister and Alquist, 2009]. Nevertheless only the capability to override an emerging and prepotent reaction makes it even possible to act in another way and to exert free will [Baumeister, 2008; Baumeister and Alquist, 2009].

On top of this it has been also claimed that the ability to constrain non-social impulses is one of the basic principles of civilized life [Tangney et al., 2004; Baumeister and Alquist, 2009].

Independently of the extensive discrepancy in the literature when it comes to define and name the concept of self-control, current theories usually agree upon differentiating self-control into trait and state aspects [de Ridder et al., 2012].
The state describes the current exertion of self-control [Baumeister and Alquist, 2009] which can fluctuate across different times and circumstances and is vulnerable to various influences like motivation [Muraven, 2008] or mood [Tice et al., 2007; de Ridder et al., 2012].

On the other hand trait self-control can be seen as the comprehensive and dispositional ability to exercise control over the self [Baumeister and Alquist, 2009]. Usually it is quite steady which is why it is frequently the subject of studies investigating beneficial effects of self-control [de Ridder et al., 2012].

As already mentioned there are not only different concepts but also several other synonyms for self-control, which include terms like willpower, self-discipline or self-regulation but also impulse control, cognitive control, executive control or delay of gratification [Duckworth, 2011].

2.1.2 Self-control measures.

Before evaluating possible benefits and consequences of high or low self-control, it is important to discuss another issue that makes it even harder to find common grounds between various different concepts and theories: namely the wide range of methods to measure self-control.

Over the years many different scales were developed which are often designed for specific behavioral patterns or population groups [de Ridder et al., 2012]. Recently a meta-analysis showed that there are over one hundred self-report questionnaires available [Duckworth and Kern, 2011]. Even so, many of them are either out-of-date or have never been applied in general populations like the “Self-Control Behavior Inventory” [Rosenbaum, 1980] or the “adapted Kendall-Wilcox Inventory for self-management” [Wills et al., 1994; de Ridder et al., 2012]. The most frequently used ones are the Self-Control Scale [Tangney et al., 2004], the Low-Self-Control Scale [Grasmick et al., 1993] and the Barratt Impulsiveness Scale [Patton et al., 1995].
The Self-control Scale from Tangney et al. is consistent with the previous mentioned definition of self-control by assessing the capacity to overrule and change behaviors [de Ridder et al., 2012]. By contrast the Low-Self-Control Scale centers on properties of low self-control like reduced tolerance to frustration, risk-seeking or impulsivity [de Ridder et al., 2012]. Similarly the Barratt Impulsiveness Scale focuses only on impulsive behaviors like absence of planning, spontaneity when it comes to making decisions and generally acting without foresight and forethought [de Ridder et al., 2012].

In this context it is of importance to emphasize that low self-control is often compared to high trait impulsiveness because impulsive individuals are constantly under the influence of their urges and act without deliberation [Carver, 2005; Friese and Hofmann, 2009; Duckworth and Kern, 2011; Vohs and Baumeister, 2011].

2.1.3 Self-control vs. Impulsiveness.

Impulsive behaviors are usually very fast, risky and improper which is why impulsivity is often linked to broader personality individualities and characteristics like psychoticism or extraversion according to the “Psychoticism, Extraversion and Neuroticism – model” [Hoyle, 2009].

Although impulsivity is typically associated with negative consequences it was proposed that there are two forms of impulsive behaviors namely “functional” and “dysfunctional” [Dickman, 1990; Vohs and Baumeister, 2011]. This indicates that being impulsive can be helpful or functional in some situations: for example in fast paced sport activities or discussions and especially to spontaneously discover unexpected prospects [Dickman, 1990; Block, 2002; Vohs and Baumeister, 2011].

Nevertheless there is empirical evidence that impulsive people are usually at a larger risk for a great number of undesirable outcomes like overspending, substance abuse, unsafe sexual and criminal behavior and overeating [Cyders et al., 2007; Krueger et al., 2007; Cyders and Smith, 2008; Vohs and Baumeister, 2011]. According to research by Whiteside and Lynam impulsivity can be divided into four other dimensions: “urgency, lack of perseverance, lack of premeditation and sensation-
seeking” [Whiteside and Lynam, 2001; Mobbs et al., 2010; Vohs and Baumeister, 2011]. Urgency can be explained as being under the influence of strong urges during negative emotional conditions while lack of perseverance is defined as the struggle to stay concentrated while engaging in a difficult task and lack of premeditation refers to the difficulties to consider possible consequences before taking part in any activities [Whiteside and Lynam, 2001; Mobbs et al., 2010]. While those three dimensions seem to be more associated with self-control, sensation-seeking is more connected to motivational aspects [Bechara and Damasio, 2002; Bechara, 2005; Bechara and Van Der Linden, 2005; Mobbs et al., 2010]. People who “seek sensations” always look out for new and thrilling experiences and often express themselves by increased alcohol and drug consumption and are even more likely to act in a dangerous and antisocial way [Carver, 2005]. Furthermore sensation seeking seems to be associated with a greater reward sensitivity which in turn is related to food consumption, increase in body weight and overeating because of an increased attention to certain food cues and stimuli like palatability and variety [Davis et al., 2004; Mobbs et al., 2010]. It is also important to differentiate between impulsiveness as a trait and common impulses and urges, which appear regardless of whether someone is high or low in trait self-control. Those usually occur involuntary [Baumeister et al., 1994] after a “latent motivation” comes together with an “activating stimulus”, which is compatible in order to satisfy this motivation [Friese and Hofmann, 2009]. For example, a latent motivation could be one’s craving for chocolate cookies and the activating stimulus would be the availability of those treats. So it seems that the idea of being in control does not necessarily mean that it is possible to avoid those urges in the first place, but rather control and eventually restrain any arising impulses due to high cognitive resources [Baumeister and Heatherton, 1996; Friese and Hofmann, 2009]. The next chapter will focus on the neurological backgrounds of self-control by reviewing especially the role of the frontal lobe in controlling social interactions, thoughts, feelings and especially cravings for food [Vohs and Baumeister, 2011].
2.2 The cognitive neuroscience of self-control.

2.2.1 The prefrontal cortex.

Many cortical regions have been associated with self-control but especially the prefrontal brain systems like the prefrontal cortex (PFC) have been revealed as being crucial to exercise self-control in many different situations [Vohs and Baumeister, 2011].

The prefrontal cortex, as displayed in Figure 1, is a part of the frontal lobes and is located in front of the primary and secondary motor cortex [Vohs and Baumeister, 2011]. It regulates “executive functions” like working memory, planning, attention control, decision making or inhibitory control [Miller and Cohen, 2001; Fuster, 2008; Tranel et al., 2008]. Those cognitive functions are essential for any kind of goal-striving behavior [Fuster, 2008].

*Figure 1: The prefrontal cortex [Bear et al., 2007]*

The PFC is also linked to systems underlying emotions, rewards and learning [Fuster, 2008; Vohs and Baumeister, 2011]. For a long time it has been even believed that the PFC is responsible for human intellect but because damages to the frontal lobe never showed any consequences in terms of intelligence psychologists have failed to find evidence for this theory [Vohs and Baumeister, 2011]. To elaborate its role in the domain of self-control it has to be subdivided into three different parts: the lateral PFC (LPFC), the ventromedial PFC (VMPFC) and the anterior cingulate cortex (ACC) [Heatherton, 2011; Vohs and Baumeister, 2011].
The capability to change behaviors and performances in order to bring them in line with long-term goals relies on a very complex relationship between each of those three PFC regions [Fuster, 2008].

2.2.1.1 Ventromedial prefrontal cortex.

The first evidence for the PFC being critical in order to control human behavior dates back to some reports of patients with brain damages in the 19th century.

A very famous case study is the one of Phineas Gage, who worked as a railroad foreman in Vermont throughout the year 1848 [Damasio et al., 1994; Heatherton, 2011]. During an accident at work a large iron bar was driven through his skull and destroyed a huge part of the VMPFC and parts of the ACC [Vohs and Baumeister, 2011]. Although Phineas Gage survived, his personality changed fundamentally after his accident. Prior to that he was known as being a dependable and truthful man, while after his misfortune his behavior was described as being rude, uncivilized and profane [Damasio et al., 1994; Harlow, 1999; Vohs and Baumeister, 2011].

While this story has certainly become famous, it lacks of further medical evidence. In contrast, a case described by Leonore Welt from 1888 is known as the first published case study that damages to the brain can lead to a change in character. After falling out of a window the described patient suffered from a severe head injury [Welt, 1888]. Similarly to the case of Phineas Gage this man’s personality also changed in a negative way. He became socially awkward and even cruel and intimidating towards others [Welt, 1888]. Further evidence was provided by postmortem analysis which showed that the damages to the brain were found in the VMPFC [Welt, 1888; Vohs and Baumeister, 2011].

Since then many other studies have confirmed these findings. For example it was found that the VMPFC is strongly connected with other regions like the amygdala and other subcortical limbic areas [Carmichael and Price, 1995]. Moreover the VMPFC is also linked with areas in the ventral striatum which are involved in reward processes [Haber et al., 1995] and other regions like the hypothalamus or the insula which are important for regulating hunger and appetite [Barbas et al., 2003; Gabbott et al., 2003].
Patients with lesions in the VMPFC usually show difficulties to regulate their social and emotional manners and might even become aggressive and develop inappropriate sexual behaviors [Grafman et al., 1996; Heatherton, 2011; Vohs and Baumeister, 2011]. Furthermore some studies show that patients with damages to the VMPC engage in binge-eating leading to overweight and obesity [Woolley et al., 2007; Vohs and Baumeister, 2011]. Such patients are not able to integrate certain norms of society, which can lead to social disinhibition [Heatherton, 2011].

2.2.1.2 Lateral prefrontal cortex.

In contrast, the lateral prefrontal cortex (LPFC) is not directly connected to limbic areas but has strong relations to the VMPFC and the ACC [McDonald et al., 1996; Bar-On et al., 2003; Vohs and Baumeister, 2011]. This is why patients with damages to the LPFC mostly have no problems following social norms and engaging in appropriate social interactions [Bar-On et al., 2003; Heatherton and Wagner, 2011]. However, they show massive deficits in executive functioning like task switching, inhibitory control or planning behaviors that consists of multiple goals [Vendrell et al., 1995; Miller and Cohen, 2001; Barceló and Knight, 2002; Vohs and Baumeister, 2011].

Shallice and Burgess conducted an experiment with patients who suffered from damages to the LPFC. They asked them to perform some tasks under real-life conditions like shopping for specific things or meeting people at a precise time of the day. While doing so the participants were unaware to the fact that they were observed the whole time by the experimenters. Results showed that these patients were not able to follow even the easiest instructions and to complete basic errands. They often entered the same shop numerous times, left the shops without paying the bills and eventually failed to buy any of the instructed things [Shallice and Burgess, 1991; Vohs and Baumeister, 2011].

This experiment clearly displayed how the different functions of the LPFC strongly depend on each other in order to achieve even the simplest goals [Shallice and Burgess, 1991; Vohs and Baumeister, 2011].
2.2.1.3 *Anterior cingulate cortex.*

Similar to the VMPFC, the anterior cingulate cortex (ACC) is also involved in regulation of emotions and reward processes [Öngür et al., 1998; Vohs and Baumeister, 2011]. Evidence from brain activation experiments revealed that the ACC is important to detect situations with response conflicts and maybe even essential to exert cognitive control [Peterson et al., 1999; Botvinick et al., 2001; Paus, 2001; Kerns et al., 2004; Carter and Van Veen, 2007].

Case studies show that damages to the ACC can lead to a condition named akinetic mutism. Although such patients are not paralyzed, they are unable to move or to talk simply because they lack the will to do so [Cairns et al., 1941; Vohs and Baumeister, 2011]. They are incapable of generating any behaviors or emotions and only talk when someone directly asks them a question [Barris and Schuman, 1953]. Some patients indicated that just as they want to exert willpower and to move or to speak suddenly a counter-will comes up and stops any further attempts [Sacks, 2011].

Some researchers hypothesized that especially the ACC activates the LPFC in situations of cognitive conflict in order to overcome desires or urges and to achieve long-term goals [Botvinick et al., 2001; Ridderinkhof et al., 2004; Vohs and Baumeister, 2011].

This short overview of some neuropsychological cases indicates how the different regions of the PFC are involved in self-regulating behaviors and what severe behavioral consequences can be caused by damages to these parts of the brain.

However, the next chapter will focus on healthy populations, by reviewing some of the empirical evidence of how high self-control may stimulate desirable and constrain unwanted behaviors.
2.3 Implications of Self-control.

2.3.1 Consequences of delaying gratification.

When it comes to discussing consequences of high and low self-control, there is literally no way around the groundbreaking work of Walter Mischel with preschoolers during the late nineteen-sixties [Mischel et al., 2011].

The intention was to investigate the principal processes of self-control when confronted with temptation. Therefore a “delay of gratification paradigm” was created, which became soon famously known as the “marshmallow test” [Mischel et al., 2011; APA, 2014].

In this paradigm the experimenters showed the children some treats with different values like for example one marshmallow opposed to two marshmallows.

After that the scientists made a proposal: the kids could either have the one marshmallow right now or the researcher would leave them alone with the marshmallow and they would have to wait until he would return unbeknownst to the length of the waiting time [Vohs and Baumeister, 2011].

They were informed that if they decided to wait they would get two marshmallows instead of only one. Additionally the children were told they could end the waiting period whenever they want by just ringing a bell but then they would forfeit the second marshmallow and only get one [Mischel et al., 1989; Lehrer, 2009; Vohs and Baumeister, 2011].

The basic idea was to examine how long it takes a young child to tolerate a delay of immediate satisfaction by generating a conflict between the desire to end the delay and get the instantly available but smaller reward (one marshmallow) or to keep on waiting for the much larger and more desired choice (two marshmallows) [Baumeister and Alquist, 2009; Mischel et al., 2011; Vohs and Baumeister, 2011].

The results showed that most of the children had a hard time resisting. Some ate the marshmallow immediately, while others were able to control themselves at least for three minutes until they rang the bell [Mischel et al., 1989; Lehrer, 2009; APA, 2014].
Based on those experiments Mischel and colleagues created the hot & cool approach to explain why self-control succeeds or fails, which will be discussed later on [Metcalf and Mischel, 1999; Mischel et al., 2011].

Furthermore those experiments did not end there, instead turned into a study of willpower and self-control over the life-span of those children [Mischel et al., 2011]. In the year 1981 Mischel started a follow-up study by sending out surveys and self-reports to parents and teachers [Lehrer, 2009]. He found out that children who waited longer to ring the bell during his marshmallow study were better at planning, concentrating and showed overall a better academic performance exemplified also by higher scores at the S.A.T. (Scholastic Aptitude Test) [Mischel et al., 1989]. Additionally they had less behavioral difficulties and were less susceptible to frustration or temptation compared to those kids who rang the bell more quickly [Mischel et al., 1989; APA, 2014].

Another follow-up study showed that a longer delay as a child was linked to higher education, greater capability to deal with stress and less substance abuse during adulthood [Ayduk et al., 2000].

Duckworth and Seligman assessed self-control in eighth grade students over the time of a school year by applying an Impulsiveness Subscale for children and short form of the Self-Control Scale also for teachers and parents [Tangney et al., 2004; Duckworth and Seligman, 2005]. Moreover the children participated in a delay of gratification paradigm, very similar to the marshmallow test, which was called the “delay choice task”. The children were offered the choice either to take one dollar right now or to return it after one week and get two dollars [Duckworth and Seligman, 2005; APA, 2014]. The results showed that children high in self-control were more often present at school, had better grades, invested more time in doing homework and less time watching television. Most interestingly, self-control was superior to the assessed intelligence quotient in prognosticating academic success [Duckworth and Seligman, 2005; Baumeister and Alquist, 2009; APA, 2014].
2.3.2 Self-control in health-related behavior.

Tangney et al. investigated self-control in undergraduate students and found similar results as Duckworth and Seligman. Students high in self-control exhibited greater academic achievements than those with low self-control [Tangney et al., 2004; Baumeister and Alquist, 2009]. Additionally, good self-control was related to more self-esteem and fewer signs of depression, anger or anxiety [Tangney et al., 2004]. Individuals high in self-control also displayed less issues with impulse control like alcohol addiction and eating disorders (e.g. binge eating) [Tangney et al., 2004; Baumeister and Alquist, 2009]. Although the study only relied on self-reports [Baumeister and Alquist, 2009], it showed that willpower as a trait seems to be also a vital part in health related behavior.

This was further investigated during the “Dunedin Multidisciplinary Health and Development Study” in New Zealand. Moffitt et al. examined self-control in a cohort of thousand children from day of birth to adulthood. Self-control was assessed at multiple times during the first ten years of life using reports of researchers, parents, teachers and children [Moffitt et al., 2011]. At the age of 32 years outcomes like cardiovascular, dental and respiratory health, inflammatory status and overweight were analyzed and summarized to a “physical health index” [Moffitt et al., 2011]. The findings showed that, even after adjusting for socioeconomic factors, high self-control prognosticated better health including less obesity as adults. In addition self-control was also associated with greater mental well-being, better finances and less drug problems [Duckworth, 2011; Moffitt et al., 2011; APA, 2014].

Wills et al. aimed to explore the relationship between self-control and eating behavior in 539 teenagers. They found out that high self-control was associated with a higher consumption of fruits or vegetables and a lower intake of saturated fats [Wills et al., 2007]. Additionally high self-control was related to more physical activity and less sedentary or inactive behavior. Those results were independent of ethnical background or parental influences [Wills et al., 2007].
Schroder and Schwarzer provided also some support for a connection between self-control and engaging in healthy behaviors. Among 381 patients self-control was assessed before heart surgery and six months after the operation. It was demonstrated that patients high in self-control reported to exercise more and eat less [Schroder and Schwarzer, 2005; Crescioni et al., 2011].

Nevertheless neither Wills et al. nor Schroder and Schwarzer focused on populations which had hoped to lose weight in the first place.

Because of that Crescioni and colleagues followed the dietary behavior and physical activities of 86 overweight participants over a 12 week weight reduction intervention. Additionally the subjects completed the short form of the Self-Control Scale every week to make sure that trait self-control scores would remain stable [Crescioni et al., 2011]. Results showed that subjects high in self-control consumed less energy overall, burned more calories during the training program and subsequently reduced more body weight compared to those with low self-control [Crescioni et al., 2011].

There are also several studies which investigated the importance of self-discipline particularly in the context of food consumption and weight-control when it comes to childhood obesity [Tan and Holub, 2011].

For example Graziano et al. explored self-control during the early years of childhood. At the age of 2 years several self-control skills like regulating of emotions, sensitivity to rewards or sustained attention were measured. Better self-control skills prognosticated a reduced risk of obesity and a general lower body mass index at the age of 5 years [Graziano et al., 2010].

Besides those early years of childhood, especially the period of adolescence is considered to be very accurate in forecasting adult health outcomes [Duckworth et al., 2010; Tsukayama et al., 2010].

High body mass index during this time is associated with obesity, diabetes mellitus or coronary heart disease in later life [Bhargava et al., 2004; Baker et al., 2007; Kindblom et al., 2009].
Francis and Susman investigated the connection between self-control capability and overweight in 1061 children, from the age 3 to 12 years. Self-control was measured using a delay of gratification paradigm with toys at the age of 3 and with food at the age of 5 years, while the child body mass index was assessed every two years [Francis and Susman, 2009].

The results showed that children who scored low in self-control in both tasks had the fastest bodyweight gains and an overall higher body mass index at all times compared to those children high in self-control [Francis and Susman, 2009].

In a comparable study by Seeyave et al. self-control was also examined by using a delay of gratification paradigm in 805 children, but at the age of 4 years. Similar to the results by Francis and Susman children with low self-control had a greater probability to be overweight by the age of 11 [Seeyave et al., 2009].

Tsukayama et al. aimed to find out if self-control at the age of 9 years is linked to obesity at the age of 15 years in a study of 844 participants. Analogous to the previous investigations also there was also a correlation between low self-control and the risk of becoming overweight. This relationship was still significant after adjusting for possible confounders like sex, socioeconomic standing, ethnic background or motherly overweight [Tsukayama et al., 2010].

Another study among 280 normal weight and obese school children in Bangkok revealed that self-discipline in time and finance management was poorer among obese children and that there were significant correlations between being overweight and low self-control [Sirikulchayanonta et al., 2011].

In summary, it can be stated that those studies outline that effective self-regulation, as a character trait, seems to be necessary for optimal functioning and well-being in many situations. On the other hand they provide no further answers as to how people control themselves in the first place and, much more important, why some of them fail while others succeed.
Particularly when it comes to explain self-control success and failure in the context of dieting or just maintaining a target weight in the obesogenic environment, a really comprehensive concept is still missing [Vohs and Baumeister, 2011].

Nevertheless there are at least some theories which allow for valuable insights into how people fail at exerting self-control. One of the earliest and most influential concepts is the Boundary model which was created by Herman and Polivy in 1984 to explain lapse-activated consumption observed in their laboratories [Herman and Mack, 1975; Herman and Polivy, 1984]. This model subsequently led the way to the construct of dietary restraint which is the main reason why self-control in the eating domain remains very controversial [Johnson et al., 2012].

2.4 Self-regulatory processes in food-rich environments.

2.4.1 Boundary model.

As stated by the boundary model “biological pressures” [Herman and Polivy, 1984] are responsible to retain food intake within specific margins [Rotenberg and Flood, 2000; Boon et al., 2002].

On the lower end hunger is responsible to keep food intake beyond a minimum level while on the other end satiety ensures that consumption remains underneath a maximum level [Boon et al., 2002]. This means that normal food consumption relies on those two boundaries by starting to eat when someone is hungry and stop when satiated [Stroebe et al., 2013].

The field between those two boundaries is known as a “zone of biological indifference” [Rotenberg and Flood, 2000; Boon et al., 2002]. In this zone, instead of “aversive biological pressures” [Higgs, 2002] only factors like social and mental stimuli define when, what and how much someone eats [Lowe and Butryn, 2007].

This means that within this zone people are neither really satiated nor hungry [Herman and Polivy, 2005], but while people do not have to eat in this state their bodies are still “biologically motivated” to do so [Lowe and Butryn, 2007].
However, this motivation relies more on external influences instead of an actual homeostatic requirement for calories and nutrients [Lowe and Butryn, 2007].

To test this theory Herman and Mack explored the consequences of preloading their subjects with either none, one or two milkshakes before taking part in a taste-test of ice-cream [Herman and Mack, 1975; Nederkoorn and Jansen, 2002; Vohs and Baumeister, 2011]. Most remarkably they found out that, while most of the subjects reduced their intake after drinking one or two milkshakes, others consumed more ice-cream compared to no preload at all [Herman and Mack, 1975; Heatherton and Wagner, 2011; Vohs and Baumeister, 2011].

They hypothesized that those individuals who indulged after the milkshakes actually have created a third self-inflicted “diet boundary” [Herman and Polivy, 1984; Boon et al., 2002; Lee et al., 2007] which was impaired by the forced preloads generating a phenomenon called “counter-regulation” [Herman and Polivy, 1984; Ogden, 2011].

It was also argued that such individuals would exhaust their cognitive resources by repetitively forcing themselves to withstand any kind of temptations [Bublitz et al., 2010], which deprives them both physically and psychologically [Lee et al., 2007].

Although these people are sometimes successful in regulating their food intake, their eating behavior is usually characterized by episodes of under- and overeating [Ruderman, 1986; Lowe, 1993; Bublitz et al., 2010] as exemplified by the mentioned preload paradigm.

Furthermore their “zone of biological indifference” seems to be broader as a result of constantly dieting and overeating which lowered the hunger boundary over time and subsequently elevated the satiety one [Boon et al., 2002; Stroebe et al., 2013].

2.4.2 Dietary Restraint theory.

Herman and Polivy labeled those individuals, who constantly try to constrain and control their consumption in order to lose or maintain an “ideal weight” [Herman and Mack, 1975; Bublitz et al., 2010; Sin and Vartanian, 2012] by using cognitive and conscious efforts, as “restrained eaters” or “chronic dieters” [Stirling and Yeomans, 2004; O'Connell et al., 2005; Hawks et al., 2008; Polivy and Herman, 2010].
Additionally this eating behavior was branded as dietary restraint [Rotenberg and Flood, 2000] which has often been defined as the “cognitively mediated effort to combat the urge to eat” [Ruderman, 1986; Bublitz et al., 2010].

The concept of counter-regulation revealed that chronic dieters are very vulnerable to disinhibition [Lowe and Butryn, 2007], considering that only a small preload was enough to induce overeating in those who seem to work so hard in controlling their food intake [Polivy and Herman, 2010].

In order to find an explanation the “what the hell effect” [Herman and Polivy, 1984] was introduced by Herman and Polivy [Herman and Mack, 1975; Papies et al., 2007]. They argued that the motivation to keep on dieting was undermined by the preload and disinhibitive thinking patterns like “I’ve blown my diet, now I might as well keep on eating” [Herman and Polivy, 1984; Boon et al., 1998] were inducing overeating or even periods of binge-eating [Hoyle, 2009].

A similar pattern has been studied in addictive behaviors, which was referred to as the “abstinence violation effect” [Marlatt et al., 2009]. This happens when addicts, who “fall off the wagon” [Heatherton and Wagner, 2011], react by uncontrollably indulging in the non-allowed substance [Baumeister and Heatherton, 1996; Heatherton, 2011].

While this explanation seemed plausible at the time it is inconsistent with recent research: The effects of counter-regulation were also observed when the diet boundary was not violated at all [Stroebe et al., 2013]. For example it was shown that restrained eaters only had to see or smell a palatable food without eating it [Nederkoorn and Jansen, 2002; Stroebe et al., 2008].

Although no diet boundary was exceeded, disinhibition and subsequent overeating appeared again which therefore cannot be explained by the concept of the boundary model [Nederkoorn and Jansen, 2002].

It is also necessary to emphasize that, although the preload effects were indeed found numerous times after the first study by Herman and Mack in the 1970s [Jansen, 1996; Nederkoorn and Jansen, 2002], the results were only replicated when the Restraint Scale was used to identify chronic dieters [Stroebe et al., 2013].
The Restraint Scale (RS) was created by Herman and Mack [Herman and Mack, 1975] to distinguish restrained eaters from unrestrained respectively normal eaters [Stroebe et al., 2013]. However, some items directly measure weight instabilities and binge eating patterns while others measure dieting or worries regarding dieting [Jansen, 1996; Brunstrom et al., 2004]. For that reason there is concern that the strong connections between overeating and dietary restraint are at least partly caused by using the Restraint Scale [Yeomans and Coughlan, 2009], which is why the validity has been questioned due to possible confounding aspects [Brunstrom et al., 2004; Johnson et al., 2012]. For example some items of the Restraint Scale directly measure disinhibited eating patterns which are more common among unsuccessful, and therefore overweight, dieters than successful ones [Stice et al., 1997; Johnson et al., 2012].

Alternative measurements for dietary restraint are the subscales of the Three Factor Eating Questionnaire (TFEQ-R) [Stunkard and Messick, 1985] and the Dutch Eating Behavior Questionnaire (DEBQ-R) [Van Strien et al., 1986; Martins et al., 2008].

In a replication of the preload paradigm from Herman and Mack [Westenhoefer et al., 1994], but using the DEBQ and the TFEQ scales instead of the RS, only participants who scored high on the subscale disinhibition of the TFEQ showed counter-regulatory responses to a preload. All other groups ate less after the preload [Westenhoefer et al., 1994; Yeomans and Coughlan, 2009]. Increased disinhibition prognosticated a higher consumption after the preload independently of the degree of dietary restraint [Johnson et al., 2012]. So usually the Restraint Scale assesses unsuccessful restrained eaters who fail to exert self-control in the eating domain but not those who succeed [Yeomans and Coughlan, 2009]. In contrast the restraint subscales of the TFEQ and the DEBQ seem to be able to identify successful dieters [Yeomans and Coughlan, 2009; Johnson et al., 2012].

Besides that, since its definition restrained eating has been associated with serious eating disorders like bulimia nervosa and binge-eating disorder [Fairburn, 1997; Neumark-Sztainer et al., 2006; Stice et al., 2008a]. But again, studies which checked for confounding elements do not support this correlation [Johnson et al., 2012]. For example Johnson and Wardle found out that associated eating disorders and
psychological problems like depression are more a result of body dissatisfaction rather than dietary restraint in adolescents [Johnson and Wardle, 2005].

Dietary restraint has also been labeled as being inefficient and even paradoxical to be a useful weight control strategy [Herman and Polivy, 1975; Johnson et al., 2012]. Nevertheless longitudinal studies show that higher restraint leads to greater weight reduction [Dalle Grave et al., 2009; Tucker and Bates, 2009] and helps to maintain the body weight better after a successful diet [Vogels et al., 2005; Vogels and Westerterp-Plantenga, 2007; Johnson et al., 2012]. However, the notion of restricting food intake remains to be a hot topic.

2.4.3 Externality theory.

After the original idea of the boundary model was dismissed, Herman and Polivy recognized that there can be a need for effective self-regulation especially in food-rich environments [Herman and Polivy, 2011; Vohs and Baumeister, 2011]. Rather than condemning the role of willpower they tried to investigate how external food cues are able to undermine self-control in the eating domain. They argued that those cues would make eating more desirable which in return overpowers self-control capacities [Herman and Polivy, 2011; Stroebe et al., 2013].

The idea that external food cues are relevant to induce (over)eating is actually an old one. Kaplan and Kaplan suggested in the 1950s [Kaplan and Kaplan, 1957] that appetite can become connected to non-nutritional aspects of food intake [Stroebe et al., 2013]. Stanley Schachter delivered first empirical evidence for this idea when he presented his “externality theory” in which he proposed that in overweight individuals eating was elicited by external food cues like dinner time or sight and smell of palatable foods [Schachter et al., 1968; Stroebe et al., 2008b].

Brian Wansink continued studying the influences of the external world on people’s eating behavior. He differentiates between an eating and a food environment [Wansink, 2004]. While the eating environment includes aspects like social and atmospheric factors, the food environment specifically refers to how the food is presented [Wansink, 2004].
In his research Wansink found many inconspicuous factors which can increase consumption e.g. size of packages or portions as well as palatability of food [Wansink, 2004]. Particularly dietary variety seems to be an important factor because satiation is reached faster when there are only a small number of food choices available [Lieberman, 2006]. For example, studies have shown that people tend to consume more food at buffets and experiments showed that bowls with jelly beans, colored in six different variations, increased consumption over sixty percent compared to those with only four different colors [Wansink, 2004; Lieberman, 2006]. Beyond that, extending diversity of foods can increase consumption independently of age or gender [Wansink, 2004].

In a recent study Prinsen et al. investigated how external signals combined with social influences would affect eating choices among healthy individuals. Separately packaged chocolate-snacks were inconspicuously presented to the subjects, while waiting to participate in an unconnected reaction-test. The social signal was presented by emptied wrappers which revealed how much someone else allegedly had or had not consumed before. Most interestingly participants followed the decisions of their believed predecessor by significantly eating more chocolate when wrappers were present [Prinsen et al., 2013]. In another study participants were presented with two options: an unhealthy or a healthy food. Once more, all subjects were influenced by the choices of others by selecting only those snacks which former subjects supposedly had consumed [Prinsen et al., 2013].

Wansink concludes that people might be unaware to the fact that their surroundings have such strong impacts on them [Wansink, 2004]. Even if they are aware of the external factors, they are oblivious to the mechanisms of how such influences alter a person’s behavior [Bargh and Morsella, 2008; Stacy and Wiers, 2010; Heatherton and Wagner, 2011].

2.4.4 Hot/cool model.

One attempt to explain self-regulatory failure in the presence of tempting food and food-cues was introduced by Walter Mischel and his “hot/cool” system [Mischel et al., 1989].
Based on the results of the marshmallow experiments Mischel and colleagues developed a new self-regulatory model to elaborate the capability to delay gratification [Mischel et al., 1989]. In order to clarify why self-control succeeds or fails it was proposed that there are two neurocognitive processes at work: a “cool” or “know” system and a “hot” or “go” system [Mischel et al., 1989; Casey et al., 2011; Vohs and Baumeister, 2011].

The “hot” system contains so called “hot spots” and is characterized by triggering very emotional, automatic and impulsive responses [Carver, 2005] and is generally involved in reward regions like the ventral striatum [Mischel et al., 1989; Casey et al., 2011; Vohs and Baumeister, 2011]. In this mode decisions are made very fast and without deliberation which is, from an evolutionary approach, essential for surviving. One reason is that it permits quick “flight or fight reactions” in the face of danger as well as it also contributes to “appetitive approach” reactions especially in the presence of stimulating cues and stimuli [Mischel et al., 1989; Casey et al., 2011; Vohs and Baumeister, 2011]. Because of its automatic nature it leads to impulsive and non-planned reactions unless someone engages in self-control and actively restrains the hot system by activating the cool one [Vohs and Baumeister, 2011].

The “cool” system contains “cool nodes” and is generally speaking cognitive and neutral. It is exactly the opposite by being more flexible, calculated and less emotional [Carver, 2005]. It is linked to the frontal lobes like the prefrontal cortex and therefore important for rational and thoughtful decisions and actions [Mischel et al., 1989; Casey et al., 2011; Vohs and Baumeister, 2011].

So how people react when confronted with a demanding situation is basically a matter of which system is in command at the current time [Carver, 2005].

Elfhag et al. provided further evidence by showing that the “hot” and impulsive behavior is especially high among obese individuals and a predictor for external eating. This means that overweight individuals seem to be sensitive to food cues but are not able to control their urges when presented with attractive food stimuli [Elfhag and Morey, 2008]. This possible connection between overeating and hypersensitivity to palatable foods will be discussed in the next chapter in the context of food-cue reactivity [Jansen, 1998].
2.4.5 Food-cue reactivity model.

The idea that some people have a heightened reactivity to external cues [Papachristou et al., 2013] originates from research regarding drug abuse [Nederkoorn and Jansen, 2002; Tetley et al., 2009; Tetley et al., 2010].

It has been demonstrated that for some people only seeing a drug can cause physiological reactions (e.g. changes in heart rate) [Tetley et al., 2009], can stimulate cravings and desires for those drugs [Drobes and Tiffany, 1997; Payne et al., 2006; Heatherton and Wagner, 2011] and is enough to increase the chances of consumption of the cued drug [Stewart et al., 1984; Glautier and Drummond, 1994; Demos et al., 2011].

Jansen and colleagues tried to find an alternative explanation for the self-control failure shown by counter-regulative eating behavior [Jansen, 1998]. According to their research episodes of binge eating are accompanied and preceded by external factors which work as strong reinforcements of food intake without the presence of actual physical hunger [Nederkoorn and Jansen, 2002; Van den Akker et al., 2013].

In their “food-cue reactivity model” [Jansen, 1998] they suggest classical pavlovian conditioning as an explanation [Drummond, 2001; Papachristou et al., 2013]. Seeing, smelling or tasting food can lead to conditioned physiological reactions [Jansen, 1998] which activate cephalic phase responses like releasing insulin or increasing salivation, pulse rate and digestive activities [Woods, 1991; Jansen et al., 2003; Coelho et al., 2009; Tetley et al., 2009; Preedy et al., 2011].

Cues can be directly associated with consumption but can also be more context-sensitive factors like home, time, emotions or thoughts [Jansen et al., 2003]. This means that a primarily neutral cue is able to predict eating (conditioned stimulus) when it is constantly combined with food consumption (unconditioned stimulus) [Preedy et al., 2011; Van den Akker et al., 2013].

For example Figure 2 demonstrates that when someone usually eats when being emotionally distressed an association between the emotion and food consumption follows.
As soon as being emotionally distressed reliably prognosticates food intake, it alone can activate cephalic phase responses and therefore eating [Preedy et al., 2011].

**Figure 2: The conditioning model of overeating [Preedy et al., 2011]**

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<td>emotion  ➔ salivation  ➔ (over)eating</td>
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Among healthy individuals fMRI studies were conducted which revealed that conditioned food, food-associated and olfactory cues are able to stimulate regions in the orbitofrontal cortex, the insula, the amygdala, the hypothalamus or certain midbrain regions [Pelchat et al., 2004; Bragulat et al., 2010; Kenny, 2011; Stroebe et al., 2013]. Signals from these regions are sent to the stomach and lead to the described cephalic phase responses [Preedy et al., 2011].

**Figure 3: Brain areas activated in response to food cues [Kenny, 2011]**
Especially the insula plays a role in processing information associated with the taste and hedonic properties of foods [Kenny, 2011].

The ventral tegmental area (VTA) and the nucleus accumbens establish the mesolimbic dopamine system [Castellanos et al., 2009; Vohs and Baumeister, 2011] which is also important for processing the motivational aspects of food [Berridge et al., 2010; Stroebe et al., 2013].

These regions have also been proven to be vital for reward processes and are displayed in Figure 3 [Berridge et al., 2010; Kenny, 2011].

Although insulin responses and salivation are normal physiological reactions [Mattes, 1997], people with tendencies to overeat show greater cephalic phase responses due to the association of cues with food consumption [Nederkoorn and Jansen, 2002].

Several other studies have shown that conditioned links between certain cues and food intake are more prominent among overweight children and that obese adult women seem to be more responsive to food cues compared to normal weight women [Tetley et al., 2009; Tetley et al., 2010].

For example Jansen et al. demonstrated that both overweight and normal weight children, between the age of 8 and 12, would eat the same quantities of food when not in a situation of temptation [Jansen et al., 2003; Preedy et al., 2011].

As soon as food cues, like smelling and tasting extremely palatable snacks, were presented the overweight kids ate much more in a subsequent taste-test than their lean counterparts. Most interestingly normal weight children ate even less when being tempted compared to be not tempted. On the other hand the results also showed that the food consumption of overweight children was strongly influenced by their increased reactivity to food cues which was assessed by measuring salivation before and after the food cues were introduced [Jansen et al., 2003; Preedy et al., 2011].

To find out why overweight people are more susceptible to palatable foods research started to investigate further possible neurologically and psychologically connections between food cue reactivity and personality traits like self-control and impulsiveness [Waxman, 2009].
2.4.5.1 Impulsiveness and cue elicited overeating.

Over the last years several studies have found positive associations between trait impulsivity and a wide range of eating disorders like obesity, binge-eating disorder or bulimia nervosa [Rydén et al., 2003; Claes et al., 2006; Nederkoorn et al., 2006a; Nederkoorn et al., 2006b].

In terms of obesity, impulsive behavior seems to contribute to both motivation and inhibition factors [Solanto et al., 2001; Dougherty et al., 2003; Nederkoorn et al., 2006a].

The inhibition factor is based on the idea that impulsive disorders essentially result from having insufficient inhibitory control [Barkley, 1997; Nederkoorn et al., 2006a]. It has been proposed that executive functions like regulating emotions and working memory capacity depend on behavioral or response inhibition [Nederkoorn et al., 2006a; Nederkoorn et al., 2010]. This is usually assessed in Stop Signal or Go/No-Go tasks as a characteristic unconnected to food intake by examining the capability of someone to constrain predominating motor reactions [Nederkoorn et al., 2006a; Jansen et al., 2009]. So deficiencies in response inhibition could therefore lead to impulsiveness [Barkley, 1997; Nederkoorn et al., 2006a].

A large series of studies have shown that inefficient response inhibition is linked to overeating, overweight and obesity [Nederkoorn et al., 2006b; Guerrieri et al., 2007; Guerrieri et al., 2008; Nederkoorn et al., 2010]. In the context of counter-regulation the preload is believed to elicit a prepotent reaction, which would be therefore eating [Jansen et al., 2009].

Besides the inhibition aspect of impulsiveness among obese individuals, there is also the proposed motivation factor which is based on the observed strong relations between impulsivity and heightened food cue reactivity due to a high susceptibility for rewards and deficits in delaying of gratification [Nederkoorn et al., 2006a; Mobbs et al., 2010; Tetley et al., 2010; Hou et al., 2011].

According to Gray’s “biopsychological theory of personality” [Gray, 1987; Gray, 1989] there are two systems at work controlling any kind of behavioral activity, namely the “Behavioral Inhibition System” (BIS) and the “Behavioral Approach or Activation
System” (BAS) [Boksem et al., 2006; Nederkoorn et al., 2006a] which take a similar approach as the “hot/cool” model by Walter Mischel.

It has been suggested that the dopaminergic BAS [Boksem et al., 2006] contains and connects both reward sensitivity and impulsiveness [Dawe et al., 2004] because it is elicited by reward cues and leads to a reward-motivated behavior [Gray, 1990; Gray and Braver, 2002; Hoyle, 2009; Braddock et al., 2011].

The cholinergic BIS [Boksem et al., 2006] on the other hand is needed to restrain any actions which would lead to possible negative consequences [Hoyle, 2009; Braddock et al., 2011].

There is evidence that psychiatric disorders like trait anxiety are linked to a high BIS, while impulsivity is strongly connected to a heightened BAS [Matthews and Gilliland, 1999; Papachristou et al., 2013].

According to Gray especially introverted individuals would score low in the BAS and high in the BIS, while it would be the exact opposite in extroverted or impulsive ones [Corr et al., 1995; Matthews and Gilliland, 1999; Papachristou et al., 2013].

The biopsychological theory of personality also states that the BIS possibly cooperates with the BAS in the ventral striatum especially in the nucleus accumbens [Boksem et al., 2006]. This assumption is in line with both animal and human studies which have demonstrated that rewards can either release directly dopamine in the nucleus accumbens or increase activation of this region [Carelli et al., 2000; Berns et al., 2001; Boileau et al., 2003; O'Doherty et al., 2003; Vohs and Baumeister, 2011].

Heightened activity in these reward regions have also been observed when people watched good-looking faces, erotic pictures or expected monetary compensation [Hamann et al., 2004; Adcock et al., 2006; Cloutier et al., 2008; Demos et al., 2011].

Especially in the obese a heightened responsivity to food cues was found in the nucleus accumbens [Stroebe et al., 2013]. This suggests that obese individuals expect a greater satisfaction, gratification and therefore reward from eating palatable snacks due to an increased Behavioral Approach System [Stice et al., 2008b].
Similarly, research by Stoeckel et al. revealed that obese women generally display an increased activation of the nucleus accumbens, amygdala and insula after looking at high caloric food pictures [Stoeckel et al., 2008; Heatherton, 2011].

In context of cue elicited over-eating some authors concluded that the unconditioned stimuli (palatable food) would activate the BAS and therefore lead to emotional changes which would make the bond between the unconditioned stimuli (food) and the conditioned one stronger [Corr, 2001; Papachristou et al., 2013]. An alternative explanation would be that impulsivity can only affect motivational qualities of the conditioned cues when a classical pavlovian conditioning has already happened [Zinbarg and Mohlman, 1998; Corr, 2001; Papachristou et al., 2013].

Either way the BAS is considered to work as a reward system which reacts to food cues by triggering a subsequent behavior to acquire those rewards [Tetley et al., 2010; Hofmann et al., 2012].

2.4.5.2 Prefrontal cortex and cue-elicited overeating.

In order to find out how the pathways of the BAS are regulated, research started to pay more attention to the possible role of the frontal lobes of the human brain.

An fMRI study revealed that people who score high in the BIS display an increased activity in the ACC while people high in the BAS had a lower activity particularly in the caudal region of the ACC [Gray and Braver, 2002; Boksem et al., 2006]. As already stated the anterior cingulate cortex is a neural structure within the PFC and essential to self-control. Especially the caudal region is considered to be essential in terms of cognitive control and so the researchers argued that a high BAS is associated with low “proactive control” [Gray and Braver, 2002; Boksem et al., 2006].

Proactive control means that someone actively uses cognitive resources in anticipation to external events (e.g. food cues) while reactive control is much more passive and is only activated when an event has already happened [Boksem et al., 2006].

So people high in the Behavioral Approach System showed decreased activation in the ACC and therefore low self-control, low proactive control and high impulsivity [Gray and Braver, 2002; Boksem et al., 2006].
This contributes to an increased activation of the nucleus accumbens and other midbrain regions and therefore to a heightened reward sensitivity and cue reactivity. This cascade of events is believed to induce overeating when food cues are present [Boksem et al., 2006; Schag et al., 2013].

Further evidence is provided by Casey and colleagues who sought out 59 former participants of the marshmallow tests by Walter Mischel during the 1960s [Mischel et al., 2011].

As already mentioned participants who showed delayed gratification as children were much more healthier, wealthier and more successful as adults compared to their counterparts, who had chosen the immediate pleasure during the experiment [Mischel et al., 1989].

Casey et al. examined inhibitory control and sensitivity to “hot” and appealing signals like happy faces. This experiment revealed that, although now over forty years old, those individuals who had struggled with delaying gratification at the age of four, had also more problems to override reactions to the hot stimuli in an adapted go/nogo paradigm [Casey et al., 2011]. In a second experiment Casey et al. used functional magnetic resonance imaging to investigate the neural processes when engaging in the same go/nogo task [Casey et al., 2011].

Overall results showed that those who displayed greater self-control as children had a greater activity in the PFC, while the ventral striatum response to hot cues was decreased. For those who performed worse at the delay of gratification paradigm it was exactly the opposite. Furthermore the results indicate that trait impulsiveness seems to be relatively steady over the life-span [Casey et al., 2011; APA, 2014].

In order to find out what exactly occurs in the brain when people actively try to control their reactions to such cues, studies of addictive behaviors were performed [Heatherton and Wagner, 2011].

For example in a study by Volkow et al. cocaine addicts were told to constrain their cravings. As a consequence the PFC was activated, more specifically the lateral prefrontal cortex, and a decrease in reward regions like the ventral striatum followed [Volkow et al., 2010; Heatherton and Wagner, 2011].
Furthermore a reduction in cue reactivity in the ventral striatum could also be replicated in healthy individuals when they were told to control their reactions in the face of money rewards [Delgado et al., 2008; Heatherton and Wagner, 2011].

In a study among 27 cigarette smokers, who tried to quit, the subjects engaged in a go/no go task during fMRI. Results showed that differences in the LPFC are strongly connected to decreases of cravings and actual smoking in real life [Berkman et al., 2011; Heatherton and Wagner, 2011].

These studies demonstrate that cravings can only be controlled by PFC areas which directly influence reward processing regions in the brain [Kober et al., 2010; Heatherton and Wagner, 2011].

Nevertheless there is still an unanswered question in terms of what exactly happens when self-control fails, especially in the context of the previously mentioned lapse-activated overeating of chronic dieters [Herman and Polivy, 1975; Heatherton et al., 1991; Heatherton et al., 1992; Heatherton et al., 1993].

In terms of the phenomenon of counter-regulation one assumption is that the preload could be considered as a “hedonic prime” which would loosen the control of the PFC over the nucleus accumbens and therefore increase the responsitivity to palatable foods [Heatherton and Wagner, 2011].

Demos et al. tested this assumption by investigating the neural mechanisms of self-control failure in an fMRI experiment. Both restrained and unrestrained eaters were either preloaded with a milkshake or just drank cold water. Right after that they were imaged while looking at non-food pictures and highly palatable food images [Demos et al., 2011].

Results showed the greatest increase in responsivity of the nucleus accumbens in restrained eaters after being preloaded with a milkshake but not after drinking water. On the other hand the opposite was observed among unrestrained eaters who experienced a greater activity in the ventral striatum after being exposed to food cues only when they had drunk water and therefore were still hungry [Demos et al., 2011]. Unrestrained eaters who had consumed the milkshake did not show any response in the reward processing brain regions. This finding is consistent with other research showing
that food becomes less satisfying when someone is satiated [Cabanac, 1971; Demos et al., 2011].

Most interestingly in the study by Demos et al. restrained eaters did not display any reaction to food cues when they only drank water which shows that under this condition dieters were still able to control themselves in the face of food stimuli [Demos et al., 2011; Heatherton, 2011; Heatherton and Wagner, 2011].

Similar findings were demonstrated in a study by Castellanos et al. in which normal weight and obese adult women took part in an eye-tracking experiment together with a visual-probe task [Castellanos et al., 2009]. This visual-probe task consisted of pictures of high and low caloric foods and measured possible differences in terms of attention for food cues. Every eye-tracking trial started with the display of a fixation cross for one second and was followed by two different food images presented next to each other (e.g. high caloric vs. low caloric) on the screen for two seconds. After that the images disappeared and the visual-probe (two different pairs of dots) was shown either in the location of the high or the low-caloric food picture. Participants had to identify the correct pair of dots by pressing buttons on the keyboard, while the main dependent variable was actually the reaction time to do so. For instance when the participant focused more on the high caloric food picture and the probe appeared in the same place (congruent) responding should be quicker than if the probe substituted the low-caloric picture (incongruent) [Castellanos et al., 2009]. Results showed that both normal and obese women had bias regarding attention for food pictures [Castellanos et al., 2009]. Nevertheless only the obese continued to have increased gaze duration after they were preloaded and despite of a decrease in self-stated hunger [Castellanos et al., 2009; Stroebe et al., 2013].

As a possible explanation for this dysregulation, a balance model of self-control failure was introduced. This model, as displayed in Figure 4, suggests that certain threats to self-control can lead to a constant increase of the subcortical activity in reward areas like the nucleus accumbens and thereby diminishes the control of the PFC in the long-term [Heatherton and Wagner, 2011].
Many of those threats to self-control are identical to factors that have been proven to trigger disinhibited eating in chronic dieters identified by the Restraint scale. For example drinking alcohol, negative and positive emotional state or ego threats [Polivy and Peter Herman, 1976; Heatherton et al., 1991; Cools et al., 1992].

Nevertheless it has to be stated that Demos et al. also used the Restraint Scale to identify chronic dieters [Demos et al., 2011]. As stated earlier in this thesis there is overwhelming evidence that those people are individuals who certainly wish to lose bodyweight but are not successful in doing so [Coelho et al., 2009].

This leads to the question how effective dieters deal with the obesogenic environment and its overwhelming presence of food-cues. After all it has been estimated that twenty percent of overweight individuals are actually able to lose ten percent of their initial body weight and also to maintain the weight loss for at least twelve months [Wing and Phelan, 2005; Preedy et al., 2011].

Based on that it was proposed that some individuals seem to have found successful coping strategies to either deal with the loss or even prevent possible self-control failure despite of the temptations of the obesogenic environment.
2.5 Coping Strategies in the presence of food cues.

2.5.1 Counteractive-control model.

Fishbach and colleagues presented a theory of “temptation elicited goal activation” [Trope and Fishbach, 2000] which basically suggests that any temptation would lead to a counteractive form of self-control [Coelho et al., 2009]. They argued that engaging in self-control to withstand any form of appealing cues would ultimately lead to a stronger connection between such temptations and the long-term goal of restricting food intake among restrained eaters [Fishbach et al., 2003; Papies et al., 2008; Stroebe et al., 2013].

In other words: as soon as dieters are exposed to certain food cues they remember watching their weight and will not indulge in the temptation [Fishbach et al., 2003; Stroebe et al., 2013].

To test this theory Fishbach et al. conducted several studies showing that temptations are able to stimulate objectives of higher importance which would later constrain the temptations [Fishbach et al., 2003].

In one experiment they allocated successful restrained eaters either to a “control prime”, a “diet prime” or a “food prime” group. In the diet prime condition participants were exposed to literature about working out and fasting. This condition was intended to trigger goals of dieting. In the food prime condition, which was supposed to stimulate desire of eating foods with high fat and sugar content, subjects were exposed to high caloric foods like chocolate and cakes together with a food journal. In the control prime condition only neutral cues were presented like economical and geographical magazines [Fishbach et al., 2003; Sheeran et al., 2013].

Results showed that subjects in the food prime condition were much quicker in distinguishing words in the context of dieting from control words in a lexical decision task [Fishbach et al., 2003]. Furthermore those who were exposed to the high caloric food cues were likelier to pick a food low in calories, like an apple, than one like a chocolate bar which is high in calories, in comparison to subjects in the other two conditions. Additionally subjects in the food prime condition stated that their goals not to overeat have been strengthened [Fishbach et al., 2003; Coelho et al., 2008a; Papies et al., 2008; Sheeran et al., 2013].
The potential self-control bolstering effects of the counteractive-control model were further backed up by Coelho et al. who showed that exposure to olfactory food cues (smell of cookies) would lead to a decrease in food-intake in restrained eaters even measured with the Restraint Scale [Coelho et al., 2008b; Coelho et al., 2009].

Nevertheless, many other studies have shown that chronic dieters usually react to food cues by increasing their food consumption (counter-regulation) [Rogers and Hill, 1989; Fedoroff et al., 1997]. Additionally the idea that food cues would have a strengthening effect on self-control seems to be inconsistent with the balance model of self-regulation [Stroebe et al., 2013].

One intriguing explanation for these inconsistencies may be found in the way how the food-cues were displayed [Coelho et al., 2008b; Coelho et al., 2009]. In studies conforming counter-regulatory effects after cue exposure palatable food was usually put directly in front of the subjects and they had to focus on the visual and olfactory properties of the food by, for example, rating the smell. In the experiments conforming the counteractive-control theory no one was asked to focus on the food-cues in a direct way and subjects were actually working on other tasks [Coelho et al., 2009]. In other words: the exposure of the participants to the food cues in the experiments by both Fishbach et al. and Coelho et al. happened in a more peripheral and distant fashion [Coelho et al., 2008b; Coelho et al., 2009]. So it seems that cue-elicited overeating not only depends on personality traits like impulsivity respective low self-control but also on the efficacy and strength of a food cue someone comes in contact with [Coelho et al., 2008b; Coelho et al., 2009].

Although the counter-active-control model does not seem to be practical, it shows that there are ways to successfully deal with the temptations of the obesogenic environment. Epstein et al. also investigated the role of food cues but took quite a different approach. Instead of distant effects they examined the influences of a recurrent exposure to certain food cues or stimuli [Epstein et al., 2011].
2.5.2 Habituation theory.

If someone is constantly exposed to a cue (e.g. a snack) the intensity of the normal cephalic phase reactions (e.g. salivation) slowly declines over time, a mechanism usually defined as habituation [Groves and Thompson, 1970; del Rosal et al., 2006; Epstein et al., 2009; Schacter et al., 2009].

It is generally seen as a very simple way of implicit learning for the reason that it does not depend on any brain regions needed for explicit learning [Schacter et al., 2009]. One famous example would be the sea slug “Aplysia californica” [Bristol et al., 2004], which has no hippocampus and only a rudimentary neural network but can still display habituation [Carew, 2000; Schacter et al., 2009].

Furthermore, there is evidence that implicit learning and habituation can happen whether or not someone is aware of the learning process [Schacter et al., 2009]. This was shown by Higgs et al. who studied mechanisms of satiety and appetite in patients with amnesia. Although the patients showed no explicit memory of a recent food intake they stated to crave the same food (sandwiches) they had eaten before considerably less than any other kinds of food [Higgs et al., 2008; Schacter et al., 2009].

This also reveals the most important property of any habituation process which is its stimulus or sensory specificity [Hetherington and Rolls, 1996; McSweeney and Swindell, 1999; Higgs et al., 2008; Epstein et al., 2009]. Epstein and colleagues showed that salivation and craving slowly habituates in children when they are repetitively exposed to certain food cues (e.g. images and smells of cheeseburgers). As soon as a new stimulus in the form of an apple pie was introduced the habituation effect was reversed [Epstein et al., 2003; Epstein et al., 2009]. This effect has been described as dishabituation [Epstein et al., 1992; Epstein et al., 2009] which is quite common and occurs for example when someone is physically satiated after a meal but decides anyway to eat more after having a look at the desserts [Epstein et al., 2009].

Studies have shown that common dishabituating factors are dietary variety, sensory stimuli or even non-food factors like watching television or attentional allocation [Epstein et al., 1993; Epstein et al., 2005; Temple et al., 2008; Epstein et al., 2009].
Moreover habituation also recuperates after a time with no contact to the cue or stimulus [Groves and Thompson, 1970; del Rosal et al., 2006]. Furthermore, the process of habituation can be enhanced when there are briefer intermissions among the presentation of stimuli and when they are generally less powerful and intense [Groves and Thompson, 1970; del Rosal et al., 2006].

Nevertheless, the question is if there are differences regarding habituation between obese and non-obese individuals. Temple et al. further investigated this notion by recruiting 34 children for a habituation paradigm in which the kids were able to collect points in a computer task (20 min) which could instantly be traded for cheeseburgers. Points received during the recovery phase (6 min) could be exchanged for French Fries, which should lead to dishabituation and response recovery. Results displayed that overweight children habituated with less speed to food-cues than children of normal weight, while there was no distinction regarding the recovery to the new food (French Fries) [Temple et al., 2007].

Usually habituation effects are studied during single session of food consumption. Because of that, Epstein et al. aimed to investigate habituation to food-cues among 32 obese and non-obese women in the long-time. They took part in a similar computer-task as seen in Temple et al. in order to earn points which they could exchange for food. One group was visited every day and therefore received the same food (macaroni with cheese) five times per day for one week while the other group was only visited on one day per week but with a total duration of five weeks [Epstein et al., 2011]. Results showed that individuals only habituated to the food when they were visited every day, independent of the weight status of the subjects. Moreover, habituation occurred quicker and was associated with a greater reduction in calorie intake compared to those who were tested only one time per week [Epstein et al., 2011].

Although it was concluded that a decrease of dietary variety in the long-term could be essential to combat obesity [Epstein et al., 2011], such an invasive approach seems highly questionable at least [Møller and Köster, 2012].

Yet the strong association of habituation with reduced food consumption remains to be an intriguing idea which is why a more gentle method was examined by extending the concept in context of mental images [Morewedge et al., 2010].
A mental image can be described as the capability of imagining certain items, happenings or episodes which are not available to someone’s mind in reality [Ishai and Sagi, 1995; Thomas, 2014]. Such visualization techniques are also part of “mental practice” which entails visualizing to carry out any kind of skill as good as possible [Baumeister et al., 2011]. Studies have demonstrated that pairing mental practice procedures with actually training the ability someone wants to improve (e.g. playing golf), will lead to better results than just physical exercise alone [Brouziyne and Molinaro, 2005; Baumeister et al., 2011]. For example mental practice has been proven to be useful in almost every sport [Markman et al., 2009] and even in making music [Theiler and Lippman, 1995], learning surgery [Sanders et al., 2004] or landing a plane [Prather, 1973; Baumeister et al., 2011].

Yet, when it comes to eating behavior results are mixed. Usually mental images of foods are strongly associated with food cravings and lead therefore to an increased intake [Kavanagh et al., 2005; May et al., 2012]. In accord with the food-cue reactivity model it seems more plausible that imagining oneself eating palatable foods would boost cephalic phase responses (e.g. salivation) and therefore provoke craving [Dadds et al., 1997; Morewedge et al., 2010] and ultimately overeating.

Nevertheless, Morewedge et al applied a mental imagery paradigm with different foods like M&M’s or cheese cubes to find out if just repetitively visualizing to eat a certain food can cause habituation and therefore diminish consumption [Morewedge et al., 2010]. They instructed people to think about consuming a food three or thirty times while the controls visualized to put coins into a laundry automat. Results revealed among others that individuals who pictured themselves thirty times to eat cheese cubes ate less in a taste-test compared to the control and to those who visualized the eating process only three times. Furthermore it was confirmed that habituation is very specific to the corresponding cue because there was no impact of picturing oneself to eat cheese cubes on subsequent intake of M&M’s [Morewedge et al., 2010]. Additionally while mental visualization reduced the reinforcing qualities of the food (wanting), there was no reduction of the hedonic assessment of the food (liking) which is in line with the habituation theory [Morewedge et al., 2010; Carr and Epstein, 2011].
In other words: the “emotive power” of the imagined food was lost due to habituation [May et al., 2012]. Morewedge et al. argued that those findings show that repetitive mental visualization procedures could be helpful for individuals who struggle with food cravings [Morewedge et al., 2010]. Nevertheless some authors have pointed out the difficulty of applying such a technique in a non-laboratory setting especially when stimulating food cues are present [May et al., 2012; Andrade, 2013]. This leads to the question how the food-cue reactivity model would apply to effective dieters.

2.5.3 Extinction of cue-reactivity.

According to Jansen and colleagues the conditioning to food cues can be unlearned but only when food cravings would not be indulged in the company of palatable foods [Preedy et al., 2011]. This means that dieters should not try to escape the temptations of the obesogenic environment because they continue to be highly responsive to food cues if they do so. Rather than trying to avert palatable snacks only direct contact to such foods would result in an elimination of learned cravings but only if dieters do not give into temptation [Preedy et al., 2011].

This means that when food intake does not accompany the conditioned food cues, the link between the conditioned stimuli and the unconditioned stimuli will be destroyed and therefore lead to a reduction of the urge to overeat [Preedy et al., 2011].

Figure 5: Relation between dieting and food-cues [Preedy et al., 2011]
This effect is described as “exposure to cues with subsequent response prevention” (ERP) [Preedy et al., 2011] and has been mostly investigated in individuals with eating disorders [Toro et al., 2003; Martinez-Mallén et al., 2007]. In the context of bulimia nervosa, patients are motivated to consume plenty of a forbidden food (= exposure) but then they are not allowed to purge (= response prevention) [Toro et al., 2003] which should lead to a slow decrease of the rate of binge-eating episodes [Preedy et al., 2011]. Nevertheless results were not always successful [Carter and Bulik, 1994; Bulik et al., 1998].

When it comes to overeating and obesity patients are certainly not encouraged to eat, but they should feel the food in their hands and smell it [Toro et al., 2003]. They are even instructed to hold the forbidden food next to their mouths but then were prohibited from actually eating it [Toro et al., 2003].

Another approach would be to expose the obese individual not only to highly palatable foods but also to other factors which trigger overeating and have been conditioned with food intake like for example negative emotions. Similar to before the overeater would be stopped from eating any of the presented foods [Preedy et al., 2011].

**Figure 6: Model of extinction of overeating [Preedy et al., 2011]**

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<th>extinction of (over)eating</th>
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<td>after conditioning</td>
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<td>cue (e.g. emotion) → cue reactivity → food intake</td>
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<th>cue exposure with response prevention (extinction)</th>
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<td>cue (e.g. emotion) → cue reactivity → no food intake</td>
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<tr>
<td>cue (e.g. emotion) → no cue reactivity → no eating</td>
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However, future experimental studies should investigate if such techniques are indeed successful for overeaters without binge eating disorder [Preedy et al., 2011]. Besides that it remains unclear how the procedure of ERP would work when external guidance is not available. Under such conditions it could be possible that the obese person would
again have to rely on self-discipline [Jansen et al., 1992]. Unfortunately it can be expected that this would lead to a vicious cycle because one of the reasons the overeater is obese in the first place is not being able to apply self-control to his or her behavior [Toro et al., 2003].

Because of this issue several researcher started to investigate potential ways to either improve self-discipline or at least prevent its failure by defining self-control as being resource-dependent and therefore able to modify [Baumeister et al., 1998; Baumeister et al., 2007; Inzlicht and Schmeichel, 2012]. One of the most influential concepts was introduced by Roy Baumeister and his colleagues with the strength/resource model of self-control [Baumeister et al., 2007].

2.6 Prevention of self-control failure.

2.6.1 A resource depletion approach.

In the late nineteen nineties Roy Baumeister and colleagues conducted a series of groundbreaking experiments with regards to self-control as a state. Those studies were based on originally made observations that self-regulatory ability seems to be declining the more someone tries to engage in self-control within a short time [Baumeister et al., 1994; Baumeister et al., 1998; Baumeister et al., 2007]. For that reason they aimed to further investigate the nature of self-control in respect of a possible limited energy resource that can be exhausted [Baumeister et al., 1998].

In one of the most famous experiments by Baumeister and colleagues male and female students, who had not eaten anything for three hours, were recruited for a bogus taste-test [Baumeister et al., 1998]. All subjects were exposed to two different kinds of food: chocolate cookies and radishes. Additionally the whole room was deliberately filled with the appetizing odor of cookies. As a next step, one group was assigned to eat (and rate) the cookies whereas the other group was told only to consume radishes. Those who had to eat the radishes were expected to require considerably more self-control in order to withstand the temptation of the much more palatable cookies. After the taste-test both groups participated in a “problem-solving task” [Baumeister et al., 1998] which contained several, unknown to the participants, unsolvable and therefore highly
unsatisfying anagram puzzles. As a dependent variable time was measured until the participants gave up on solving the puzzles. Moreover a control group also tried to solve the puzzles consisting of only sated individuals who did not come in contact with radishes or cookies in the first place [Baumeister et al., 1998].

Results indicated that individuals in the radishes group, who were not allowed to eat cookies and therefore highly tempted, displayed a weaker self-control performance because they gave up more easily and quickly on the puzzle task than those in the cookie or control group [Baumeister et al., 1998; de Ridder and de Wit, 2008; Vohs and Baumeister, 2011; Alquist and Baumeister, 2012].

Baumeister and colleagues argued that if self-control would be a skill or a “knowledge-structure” it would either stay stable or even increase when being exerted [Baumeister et al., 1998; Baumeister et al., 2007]. Though this was not the case, so it was hypothesized that resisting temptation in the first task led to some sort of a “psychic cost” [Glass et al., 1969] in the second one [Baumeister et al., 1998; Baumeister et al., 2007].

This phenomenon was further elaborated as “Ego-Depletion” and the theory of the strength or resource model of self-control was introduced [Baumeister et al., 2007; Hagger et al., 2010].

The central postulation of this model is that self-control relies on an unknown energy source, which is limited and can be therefore exhausted after someone has already exercised self-control [Muraven et al., 1997; Baumeister et al., 1998; Baumeister et al., 2007; de Ridder and de Wit, 2008; Hagger et al., 2010; Inzlicht et al., 2014]. Because of that a similarity between self-control and muscle strength was suggested [Muraven and Baumeister, 2000] especially due to the fact that willpower capacity declines with every attempt to exercise self-control [Baumeister et al., 2007]. This is comparable to muscles which can get exhausted and need to relax after physical effort [Baumeister et al., 2007; Baumeister and Alquist, 2009].

Another feature of the strength model is that mental energy may be unspecific and is needed for many different applications of self-discipline [de Ridder and de Wit, 2008; Hagger et al., 2010].
The effects of ego-depletion are usually induced by applying a classic “dual task paradigm” [Hagger et al., 2010] which entails two unconnected self-regulatory tasks [Tice and Ciarocco, 1998; Baumeister et al., 2007]. In such a dual task paradigm participants are either allocated to a control (low ego-depletion) or intervention (high ego-depletion) group [Hagger et al., 2010]. Subjects in the high ego-depletion condition have to participate in two sequential self-control tasks while the control participants also have to take part in two tasks but only the second one should demand self-control strength [Baumeister et al., 2007; Hagger et al., 2010]. As a result the subjects within the high ego-depletion condition should perform worse on the second task as a consequence of exhausted resources [Baumeister and Vohs, 2007].

For example in one study subjects in the high ego-depletion condition inhibited any emotions while watching a sad film whereas participants in the control group did not control their affective reactions [Muraven et al., 1997]. Results showed that those who were depleted were not able to squeeze a common handgrip as long as subjects in the control condition [Muraven et al., 1997]. Squeezing the handgrip is a common measure of self-control because people need to ignore their urge to quit this uncomfortable task [Muraven et al., 1997; Muraven and Slessareva, 2003; Alberts et al., 2011].

Also several studies have established that ego-depletion is not triggered by any alterations in mood or frustration [Muraven et al., 1997; Baumeister et al., 1998; Alquist and Baumeister, 2012]. To find out if ego-depletion is just caused by exhaustion or tiredness Vohs and colleagues deprived their subjects of sleep while participants in the control were rested [Vohs et al., 2011]. After twenty-four hours all subjects were instructed to watch a film while those in the high ego-depletion group were told to overpower their affective and facial responses while participants in the control could react as they wanted [Vohs et al., 2011]. The second task consisted of a computer aggression game in which all winners, who were actually selected randomly, could blast at other players an individually chosen volume which correlated with perceived amount of hostility. The more aggressive people acted the stronger depleted they were but results showed that tiredness did not have any effects on hostility/self-control [Vohs et al., 2011; Alquist and Baumeister, 2012].
2.6.1.1 Consequences of ego-depletion.

Since Baumeister’s first experiment over hundred studies have explored the ego-depletion effects and seem to agree with the idea that self-control could rely on a limited supply [Inzlicht et al., 2014]. Moreover the impacts of ego-depletion have been proven to be steady among various fields of self-control [Hagger et al., 2010]. For instance studies have also shown that ego-depleted individuals are at a higher risk of impulsive buying, giving into primitive sexual urges and are easily provoked or also quickly convinced by questionable opinions [DeWall et al., 2007; Gailliot and Baumeister, 2007b; Vohs and Faber, 2007; Wheeler et al., 2007].

Furthermore some experiments also investigated possible influences of ego-depletion on health-related activities. In one study ego-depletion was induced by inhibiting a “forbidden thought”, while the control group was only instructed so solve easy math equations [Muraven et al., 2002]. Afterwards, all subjects took part in a bogus beer taste-test and were told they could drink their fill. Nevertheless it was also stated that they would have to participate in a following test of their driving skills. This information aimed to offer a motivation to restrain alcohol consumption in order not to fail the test [Muraven et al., 2002; de Ridder and de Wit, 2008].

Results indicated that ego-depleted individuals were not able to control their alcohol consumption regardless of the driving test. Furthermore especially those who already had problems in controlling their alcohol intake in the first place were much more inclined to indulge in drinking when their self-control capacities were diminished [Muraven et al., 2002; de Ridder and de Wit, 2008].

Similar to those findings, Vohs and Heatherton proposed that a breakdown of self-control in the eating domain would be more likely among dieters or restrained eaters [Vohs and Heatherton, 2000]. This assumption would be in line with the observed counter-regulatory effects and also with the balance model of self-control [Vohs and Heatherton, 2000; Heatherton and Wagner, 2011].

In a study among restrained and unrestrained eaters highly palatable and fattening foods were positioned either in front of the subjects (ego-depletion condition) or at the other end of the laboratory (control condition) while they watched a video. In addition half of
the subjects were informed they could eat the foods if they want, while the other half was instructed not to and therefore a “high and low-tempting condition” was created [Vohs and Heatherton, 2000]. After watching the video clip all subjects participated in a taste test of ice-cream. The amount of consumed ice cream was used as the main dependent variable.

Results showed that restrained eaters who had to withstand the urge to indulge in the palatable snacks next to them, consumed much more ice cream than unrestrained eaters in the same temptation condition [Vohs and Heatherton, 2000; Vohs and Baumeister, 2011].

In a second study by Kahan et al. restrained and unrestrained eaters were ego-depleted by applying a conflict condition based on a group-interaction method [Crutchfield, 1955] and then invited to taste and rate three different kinds of cookies. As the dependent variable the amount of eaten cookies was measured [Kahan et al., 2003]. Consistent with the findings by Vohs and Heatherthon restrained eaters consumed more food after their self-control resources were exhausted compared to unrestrained eaters [Kahan et al., 2003]. It was concluded that chronic dieters would rely strongly on their self-control resources to constrain their food intake. For example in a social situation (e.g. a party) a restrained eater would need a great amount of self-discipline to withstand any food related temptations. As a consequence of constantly restraining such urges, the chronic dieter would become ego-depleted and more likely to overeat in the next tempting situation [de Ridder and de Wit, 2008].

Nevertheless both studies used the Restraint Scale, which tends to identify rather unsuccessful than successful dieters as stated elsewhere. Moreover body mass index was not obtained although increased dietary restraint correlates with high BMI [Schur et al., 2010; Hagger et al., 2013].

For that reason a recent study aimed to investigate the effects of ego-depletion among individuals with high and normal body mass index [Hagger et al., 2013]. Results showed that only those individuals with a high body mass index ate more in a subsequent taste-test when being ego-depleted. Conversely, consumption of participants with a normal body mass index was not affected by ego-depletion [Hagger et al., 2013].
2.6.1.2 Physiological costs of ego-depletion.

In contrast to several other, rather theoretical, concepts of self-control failure, the strength model even suggests possible physiological origins [Alquist and Baumeister, 2012].

For example Inzlicht and Gutsell used electroencephalography (EEG) measures to investigate the neural pathways underlying ego-depletion [Inzlicht and Gutsell, 2007]. They applied an emotion inhibition task to provoke ego-depletion and used as a second one the Stroop task, which specifically involves inhibitory control [Ellis et al., 2004]. Additionally among all subjects error-related negativity (ERN) was examined throughout the task. ERN is a part of an event-related potential (ERP) which can be described as an electrical brain signal or waveform [Falkenstein et al., 1990; Gehring et al., 1993; Godlove et al., 2011; Alquist and Baumeister, 2012]. An ERN occurs as a reaction to errors [Nieuwenhuis et al., 2001] and is assumed to descend from the ACC [Van Veen and Carter, 2002; Inzlicht and Gutsell, 2007]. The results of the study revealed that ego-depleted subjects displayed a decrease in ERN signaling compared to the non-depleted controls. This means that ego-depletion impairs the capability to successfully screen for errors and conflicts [Inzlicht and Gutsell, 2007; Baumeister and Alquist, 2009; Alquist and Baumeister, 2012].

Segerstrom and Nes recommended another way to measure self-control strength by examining heart rate variability (HRV) [Segerstrom and Nes, 2007]. In the ego-depletion condition subjects had to resist eating cookies and eat the carrots instead while it was the opposite in the control group. After that all participants had to work on unsolvable anagram puzzles while HRV was measured and the time was examined until they voluntarily gave up [Segerstrom and Nes, 2007]. Results indicated that ego-depleted subjects had higher HRV than subjects in the control condition [Segerstrom and Nes, 2007]. It was concluded that homeostatic processes like steadying the heart rate could be impaired by ego-depletion and therefore depend on the unknown mental energy resource [Segerstrom and Nes, 2007; Baumeister and Alquist, 2009; Alquist and Baumeister, 2012].
In order to identify the rather ambiguous mental energy resource Gailliot and colleagues investigated the role of glucose in the bloodstream [Gailliot and Baumeister, 2007a; Gailliot et al., 2007]. It has been known that glucose provides energy for the brain [Weiss, 1986; McNay et al., 2001; Laughlin, 2004]. Research has also shown that when glucose levels are diminished cognitive and social functioning is compromised and therefore can lead to memory loss, fear, disorientation or strange demeanour [Benton et al., 1994; Benton et al., 1996; Donohoe and Benton, 1999a; Donohoe and Benton, 1999b; Scholey et al., 2001; Fairclough and Houston, 2004; Gailliot et al., 2007]. It was argued that because glucose is necessary for cerebral processes it can therefore be the source needed for so many different self-regulatory tasks [Gailliot and Baumeister, 2007a]. Gailliot et al. conducted a series of ego-depletion experiments and measured, before and after applying the dual task paradigm, blood glucose levels. It was claimed that exercising self-control lessens the extent of glucose in the blood. Likewise low glucose levels after the first task were associated with poor performance on the second task [Gailliot et al., 2007]. The authors reasoned that the brain requests more glucose throughout efforts of self-control [Gailliot and Baumeister, 2007a]. Yet this assumption remains to be controversial. Several studies have shown that alterations in blood glucose levels, witnessed before, throughout and afterwards such effortful tasks, are improbable to be caused by changes in the brain’s glucose stock or influx [Messier, 2004; Gibson, 2007; Kurzban, 2010]. Research has also established that the brain’s glucose intake of the brain is actually quite stable and would not be further affected by such tasks [Clarke and Sokoloff, 1999; Lennie, 2003; Kurzban, 2010]. Lately the presented results from Gailliot et al. were criticized by Kurzban and colleagues. They argued that the evidence presented by Gailliot et al. actually contradicts their own claims [Kurzban, 2010; Kurzban, 2011]. For example subjects in the ego-depletion condition had originally much higher blood glucose levels than participants in the control condition. Therefore the drop in blood glucose could be just the result of having unusually high levels in the first place [Kurzban, 2010; Kurzban, 2011]. A closer look at the data also showed that there was no decrease in glucose levels
among participants who had been depleted by self-control tasks [Kurzban, 2010; Kurzban, 2011].

Likewise Molden et al. found no evidence in a recent experiment that applying self-control would influence the quantity of blood glucose. In contrast to Gailliot et al. measurement was conducted under much more accurate and controlled conditions [Molden et al., 2012].

So while it seems that blood glucose is rather unlikely to be the mysterious source that gets drained, research has shown that glucose could be at least in some ways relevant for self-control [Inzlicht et al., 2014].

### 2.6.2 Offsetting ego-depletion.

#### 2.6.2.1 Glucose supplementation.

Even though difficult self-control tasks seem to be irrelevant regarding glucose in the blood, there is evidence that glucose intake can indeed improve self-disciplinary efficacy [Inzlicht et al., 2014]. For example studies in which glucose levels were augmented observed less aggression and improvements in working memory among subjects [Denson et al., 2010; Owen et al., 2012; Inzlicht et al., 2014].

Gailliot et al. also examined the consequences of glucose supplementation among ego-depleted individuals. After the first self-control task subjects were given a sugar-drink (glucose group) while others consumed a beverage with synthetic sweetener containing zero calories (control group) [Gailliot and Baumeister, 2007a]. Results showed that ingestion of sugar supposedly reestablished willpower because depleted individuals in the control condition made significantly more mistakes in the Stroop task in comparison to those in the glucose condition [Gailliot and Baumeister, 2007a; Vohs and Baumeister, 2011].

Masicampo and Baumeister provided further evidence for the possible role of glucose supplementation in order to combat ego-depletion. Similar to the findings by Gailliot et al. self-control was improved only among ego-depleted participants who drank the glucose beverage [Masicampo and Baumeister, 2008; Vohs and Baumeister, 2011].
Some researchers started to question if ingestion of carbohydrates would really be needed to offset ego-depletion effects.

For example in an ego-depletion experiment by Molden et al. subjects were instructed to flush their mouths with either some kind of sugary beverage or a placebo drink without glucose after the first self-control task. Results showed that simply rinsing with glucose solution was enough to inhibit ego-depletion and bolster self-control. It was concluded that because carbohydrates do not have to be metabolized, just tasting sugary drinks possibly leads to increases of motivation during the second task [Molden et al., 2012; Sanders et al., 2012].

Most recently those findings were successfully replicated by Sanders and colleagues as well as by Hagger and Chatzisarantis. These studies provided further support for the proposition that glucose influences self-control in a non-metabolic way [Sanders et al., 2012; Hagger and Chatzisarantis, 2013].

According to Chambers et al. glucose in the oral/mouth cavity is strongly connected with a heightened activity of brain sections like the ACC and the ventral striatum which are involved in self-control and reward mechanisms [Chambers et al., 2009; Sanders et al., 2012].

Hagger and Chatzisarantis concluded that just tasting glucose may have led to a heightened activity of the ACC and therefore improved self-control. Additionally it was suggested that glucose worked as a rewarding stimulus that was implicitly linked to the ego-depletion task and therefore stimulated motivation regarding further tasks [Hagger and Chatzisarantis, 2013].

In a recent study Lange and Eggert conducted two experiments in order to further investigate the role of glucose in the context of ego-depletion [Lange and Eggert, 2014].

The first experiment aimed to reproduce the results by Gailliot et al. and therefore was designed to examine possible anti-ego-depletion effects of glucose ingestion. At the beginning blood glucose levels were measured and participants were ego-depleted by both a selective attention task and a delay discounting task [Lange and Eggert, 2014].
After that subjects consumed either a drink with glucose (intervention) or a sweet tasting beverage without calories (control). After fifteen minutes blood glucose levels were measured again and subjects participated in the discounting task for the second time [Lange and Eggert, 2014]. Results showed that the blood glucose levels in the control condition were not affected by the self-control tasks which is in line with previous mentioned opinions that exerting self-control would not lead to alterations of blood glucose levels [Kurzban, 2010; Molden et al., 2012]. However, glucose supplementation also did not have any impact on the performance in the self-control tasks either [Lange and Eggert, 2014] which is contradictory to prior stated findings.

The second experiment investigated the effects of oral glucose sensing on self-control resources by just flushing/rinsing the mouth with a sugary liquid. The overall aim was to find out if sensing glucose would influence self-control as either a reward or as a “discriminative stimulus” [Lange and Eggert, 2014]. Nevertheless results displayed that rinsing with a glucose fluid had no effects on ego-depletion which means that the results from Molden et al., Sanders et al. and Hagger and Chatzisarantis could not be confirmed [Lange and Eggert, 2014].

Further research will be needed to clarify those conflicting findings and elaborate if the role of glucose sensing and ingesting may have been exaggerated in earlier experiments [Lange and Eggert, 2014].

Besides that, the question remains how a possible increase of self-regulatory resources, by glucose consumption or just tasting sugary solutions, would apply to the counter-regulation effects observed among restrained eaters. Those individuals consumed a preload which is also rich in sugar but instead of increasing willpower they failed at exerting self-control by indulging in palatable foods [Herman and Mack, 1975; Polivy and Herman, 2010; Vohs and Baumeister, 2011].
2.6.2.2 Conservation and automation.

As stated before Baumeister and colleagues hypothesized that applying self-control resembles physical exercise [Baumeister et al., 2007]. In their muscle comparison they proposed that people who anticipate to exert self-control start to preserve their resources [Baumeister et al., 2007; Alquist and Baumeister, 2012]. Also from an evolutionary perspective it is rather improbable that any acts of self-control would inevitably cause a complete mental exhaustion [Alquist and Baumeister, 2012].

Muaven et al. found out that ego-depleted individuals who anticipated to need self-control later on for a third task, displayed inferior performances on the second task compared to those who did not anticipate a third one [Muraven et al., 2006]. On the other hand those who obviously conserved their self-regulatory strength during the second task performed better on the third [Muraven et al., 2006].

With regards to the muscle analogy, Baumeister and colleagues also theorized that when ego-depletion is the result of conserving cognitive resources, people should still be able to exert self-control under certain conditions [Baumeister et al., 2007].

For example, Muraven and Slessareva tested the conservation theory across two experiments in which subjects’ motivation was manipulated in order to do well on the self-control tasks by either offering reimbursements (e.g. money) or by informing good results would be valuable for others [Muraven and Slessareva, 2003]. Results demonstrated that the greater subjects were motivated the more probable they were to mobilize their energy reserves instead of preserving them [Muraven and Slessareva, 2003].

Another possible way to avoid ego-depletion is to apply automatic processes which do not rely on self-regulatory resources [Alberts et al., 2007; Adriaanse et al., 2011]. In comparison to controlled processes, which are adaptable but effortful, automation is usually effective but inflexible [Muraven and Baumeister, 2000].

Web and Sheeran used implementation intents [Webb and Sheeran, 2003] which explicitly target a certain behavior in a specific situation [Alberts et al., 2007]. For example: “If I come upon situation x, I will start goal-directed behavior y” [Webb and
Sheeran, 2003; Alberts et al., 2007]. Results showed that implicitly implementing when and how to perform throughout the first task, led to better results during the second one and therefore counteracted ego-depletion [Webb and Sheeran, 2003; Alberts et al., 2007].

Alberts and colleagues also investigated if subconsciously priming “persistence” can diminish ego-depletion by triggering automatic behavioral patterns [Alberts et al., 2007].

Findings indicated that ego-depleted individuals who were primed with persistence were able to maintain their self-control resources [Alberts et al., 2007].

It was concluded that conserving self-regulatory resources or initiating automatic processes are effective methods to reduce ego-depletion effects but only in the short term [Baumeister and Alquist, 2009; Hagger et al., 2010].

2.6.2.3 Boosting self-regulatory strength.

The strength model of self-control suggests that self-control performance gets worse in the same way as a muscle gets fatigued but it is also known that exercises lead to enhancements of muscles in the long-term [Baumeister et al., 2007]. Therefore Baumeister and colleagues argued that frequent exertions of self-discipline could also improve self-regulatory capacities in the long run [Baumeister et al., 2006; Baumeister et al., 2007].

In a study by Muraven et al. handgrip strength, as the dependent variable, was measured before and after a thought suppression task to induce ego-depletion. After that subjects were asked to join in self-control activities for fourteen days. One intervention group had to carefully track their food consumption in form of food diaries while a second intervention group was told to maintain a good posture (e.g. sitting straight up) as regularly as possible [Muraven et al., 1999]. Results demonstrated that such self-control practices led to better performances in self-control tasks which were unconnected to the interventions [Muraven et al., 1999; Baumeister and Alquist, 2009].
Oaten and Cheng investigated possible associations between physical workouts and self-control. Before and after the intervention program (containing endurance and weight training) all subjects participated in a dual task paradigm [Oaten and Cheng, 2006]. Results revealed that the effects of ego-depletion decreased after two months of physical training which also led to enhancements of self-control in generally health-related behaviors (e.g. less alcohol and less smoking) [Oaten and Cheng, 2006; Vohs and Baumeister, 2011].

In another study ego-depletion was measured before and after a four-month financial intervention program [Oaten and Cheng, 2007]. During this program subjects had to constantly monitor their finances. At the end of the intervention ego-depletion effects were weaker than before [Oaten and Cheng, 2007]. Additionally subjects smoked less, learned more and consumed more healthy food [Oaten and Cheng, 2007; Baumeister and Alquist, 2009].

Nevertheless some studies which aimed to increase self-control strength were not successful in doing so. More research is required to find reliable techniques to improve self-control and to investigate which of those are most effective [Baumeister and Alquist, 2009].
2.7 Research questions.

Latest research suggests that repeatedly imagining eating a certain food will cause a decrease in consumption of the imagined food in a subsequent taste-test supposedly through habituation [Morewedge et al., 2010; Missbach, 2012].

The initial idea for the empirical part of the thesis was to a) replicate these findings under different conditions and b) critically investigate the habituation theory with mental images in a state of cognitive impairment [Morewedge et al., 2010].

First, walnuts were used for the mental imagery paradigm and the subsequent taste-test in contrast to former studies which used foods like M&Ms, cheese cubes or gummy bears [Morewedge et al., 2010; Missbach, 2012]. It was speculated that if the mental imagery paradigm would still lead to a decrease in food intake with an allegedly healthy snack it would be in favor of the habituation theory and not due to simply being more aware to an upcoming consumption of a taboo-food. Walnuts are generally recognized to be a healthy and palatable snack while still high in calories [Belitz et al., 2001]. The amount of consumed walnuts served as the most important dependent variable in this experiment.

Second, the study was designed to test all participants individually which did not happen in the experiments by Missbach and Morewedge et al.

Third, the decision was made to test the mental imagery paradigm following a cognitive demanding task. It was hypothesized that the task to repeatedly imagine eating a certain food would need cognitive resources. This idea was primarily based on the feedback given by the participants in a previous study [Missbach, 2012]. They stated to have experienced severe problems to withstand the desire to quit the task which is why it was chosen to test the mental imagery paradigm in the context of the strength/resource model of self-control [Baumeister et al., 2007]. This model states that the exertion of self-control relies on an unknown mental energy source which is considered as limited and exhaustible [Hagger et al., 2010]. Analogous to a muscle which can become fatigued after working out people’s self-regulatory
reserves can be diminished which leads to a state of ego-depletion [Baumeister et al., 1998; Alberts et al., 2008; Vohs and Baumeister, 2011; Hagger et al., 2013].

Using a dual task paradigm ego-depletion can be induced by having people to take part in two consecutive self-control tasks [Hagger et al., 2010].

It was hypothesized that, if the procedure of repeatedly imagining a certain task requires the same energy resource as self-control, it would be impaired in a state of ego-depletion. Under this condition no decrease of food intake in a subsequent taste-test of walnuts was expected.

Moreover it was theorized that the state of ego-depletion could also increase food intake. This assumption was based on previous studies, which showed that especially unsuccessful restrained eaters and individuals with a high body mass index are highly vulnerable to overeating when resources have been exhausted [Vohs and Heatherton, 2000; Hagger et al., 2013].

So the german version of the sub-scale for restrained eating of the Dutch Eating Behavior Questionnaire was included to identify chronic dieters [Van Strien et al., 1986] and the Perceived Self-Regulatory Success in Dieting Scale (PSRS) to specifically detect successful restrained eaters [Meule et al., 2012].

Additionally the german version of the Barratt Impulsiveness Scale (BIS-15) was applied to identify individuals with high trait impulsiveness and therefore low self-control as a trait [Meule et al., 2011].

According to the strength/resource model self-control would be compromised after the first task which should not be the result of fluctuations in fatigue or mood [Hagger et al., 2010]. In order to assess the current mood a german version of the profile of mood states was used together with a manipulation check right after the first depleting task [Dalbert, 1992].

On top of this also other possible influential variables on food intake were assessed like body mass index (BMI), appetitive parameters and liking of walnuts before and after the taste-test.
3 Materials and Methods.

3.1 Ethics statement.

A written informed consent form was obtained from every participant previous to data collection.

3.2 Participants.

Exclusively female participants were recruited via online forums, social networks and message boards of University of Vienna. Most of them were undergraduate students of nutritional sciences (N=86; mean age=24.52, SD=3.18) who volunteered to take part in the experiment. They were blinded to the true intention of the study, believing to participate in a common acceptance test of different kinds of organic and conventional walnuts. They were told to refrain from eating at least three hours before the experiment and received a reward for their participation in the form of a lottery ticket.

3.3 Design.

The study was carried out during the semester break of University of Vienna in February 2014 in order to use temporarily vacant seminar rooms to conduct the experiments. All subjects were tested individually in single sessions of 30 up to 40 minutes by the experimenters. They were asked to perform two tasks camouflaged as “tests of mathematical and mental imagination skills” prior to the acceptance test for walnuts. In order to disguise the actual objective of the study these tasks were explained to the participants as being “influential on how people would taste and rate organic foods”. The qualitative results of the acceptance test were not of interest for this study and therefore not further analyzed. Participants were randomly assigned to a 2 (Ego-Depletion: high vs. low) x 2 (Mental Imagery: walnuts vs. coins) between-subjects design using an online randomizer tool [Urbaniak et al., 2007].
As displayed in Figure 7 there were four different groups:

E-L, which stands for ego-depletion low, and E-H, which is short for ego-depletion high, were combined with both MI-W, short for mental imagery with walnuts, and MI-C, short for mental imagery with coins.

- Ego-Depletion low & Mental Imagery walnuts (intervention I)  
  Ego-Depletion low & Mental Imagery coins (control I)
- Ego-Depletion high & Mental Imagery walnuts (intervention II)  
  Ego-Depletion high & Mental Imagery coins (control II)

**Figure 7: Intervention model:**

3.4 Experimental tasks.

3.4.1 Ego-Depletion task.

In order to induce ego-depletion the classic dual-task procedure was adapted by applying a counting task which is based on a task to assess the automatization problems in patients with dyslexia [Fawcett et al., 1996; Webb and Sheeran, 2003]. Subjects in the ego-depletion high condition (E-H) were told to count backwards from thousand in multiples of seven. While doing so they were instructed to stand only on
one leg. Moreover they were informed that it is important to be mathematically correct and that they would have to start from the beginning if they lost their balance. Also any mistakes would be clearly visibly noted for the participants. This procedure has been proven to evoke ego-depletion in the past because participants have to resist the desire to quit this exercise due to their struggle of trying not to lose balance while engaging in a complicated counting task [Webb and Sheeran, 2003; Hagger and Chatzisarantis, 2013; Hagger et al., 2013]. Subjects in ego-depletion low condition (E-L) were instructed to count backwards from five-hundred in multiples of five and standing on both legs. In contrast to the high ego-depletion group no mistakes were noted. Both tasks were limited to a duration of five minutes which was unbeknownst to the subjects.

3.4.2 Mental Imagery task.

After the Ego-Depletion tasks (high and low) all participants were subjected to the mental imagery paradigm which was used as the second task in the dual task paradigm. The same instructions were applied as in a previous study [Missbach, 2012]. Participants in the walnuts condition (MI-W) were asked to imagine repeatedly eating walnuts by closing their eyes and thinking about a bowl filled with those nuts. Next they were instructed to imagine taking out one nut and to look at it, smell it and then chew and swallow it. As soon they have finished this procedure they should open their eyes, make a mark on a piece of paper and repeat it [Missbach, 2012]. Participants in the coins condition (MI-C) were instructed to imagine repeatedly putting a 50 cent coin into a laundry machine. This task also included motor action because participants were instructed to think about grabbing a coin out of a bowl in front of them and then imagine looking at it and putting it into the laundry automat. Moreover the coin had a similar size to a walnut and therefore served as a similar but neutral control task to the walnuts condition [Missbach, 2012]. While the participants completed this task the experimenter left the room and returned as soon the participant ringed a bell signaling to have finished the task. The amount of repetitions was for all groups the same. Previous research showed that especially a number of repetitions between thirty [Morewedge et al., 2010] and thirty-
six [Missbach, 2012] would lead to a decrease in food intake via habituation. However, in this experiment the number of repetitions was set at eighteen mainly because of two reasons: First, it was hypothesized that the experimental setting would allow for a more individual and personal instruction of the mental imagery paradigm and therefore would get along with a lower number of repetitions. Second, it was feared that because of the overall extensive procedure more repetitions would be too time-consuming and participants would be inclined not to continue with the experiment.

3.5 Procedure.

For every participant four different brands of walnuts were filled into four identical bowls. Walnuts were weighed before the arriving of the participants and again after they left using a scale with three decimals places. The difference was calculated, which resulted in the consumed quantity of walnuts in gram. After the participants were greeted by the experimenter they were asked to fill out questionnaires to indicate their current hunger and their overall liking of walnuts by using visual analogue scales. They were also questioned regarding the point of time of their last food consumption before the experiment. Next all participants were asked to stand up for the test of mathematical ability which in fact was either the high or the low ego-depletion condition as described before. After that participants were asked to fill out three manipulation check items including measures of effort, difficulty and fatigue which was adapted and translated from similar studies [Webb and Sheeran, 2003; Hagger and Chatzisarantis, 2013; Hagger et al., 2013]. Besides that subjects were also asked to rate their current mood by completing the german version of the profile of mood states [Dalbert, 1992]. Afterwards the experimenters introduced the second task as a test of their “power of imagination”, which in fact was the mental imagery paradigm, either with walnuts or coins, as used in previous studies [Morewedge et al., 2010; Missbach, 2012]. Subsequently all subjects were asked to participate in a taste and rate task of four different kinds of walnuts which were all weighed before the experiment unknowing to the participants. Each bowl was filled with 25-30g of walnuts and therefore every
participant was presented with approximately 100-120g of walnuts in general. Participants were instructed to rate all four products in terms of taste, smell, texture and consistence. Additionally they were informed that one of those products is actually organically grown and that the main task would be to figure out which product that could be.

The experimenter told the participants that they were allowed to consume as much of the nuts as they desired and could also take as much time as needed, while in reality participants were only limited to 10 minutes.

During the taste and rate test the experimenter left the room and was summoned again by ringing the bell when participants completed the task. Afterwards participants were asked to complete the sub-scale for restrained eating of the Dutch Eating Behavior Questionnaire [Van Strien et al., 1986], the Barratt Impulsiveness Scale [Meule et al., 2011] and again current hunger and liking of walnuts which were assessed by visual analogue scales.

As a last point participants reported their age, weight, height and answered the control question for the mental imagery intervention whether or not they conducted this task. Finally participants were thanked for their cooperation, received a lottery ticket as a gift and were dismissed. Afterwards the experimenter weighed the remaining walnuts to determine the amount that has been eaten.

*Figure 8: Study Design*
3.6 Measures.

3.6.1 Mood.

Positive and negative emotional states were examined to be certain that the ego-depletion effects on the mental imagery tasks are not influenced by emotional changes. The German version of the profile of mood states was used [Dalbert, 1992]. After an initial question “How do you feel right at this moment?” there are 19 different items in terms of grief (n=3), desperation (n=3), rage (n=3), tiredness (n=4) and positive mood (n=6) on seven-point Likert scales which are ranging from 1 (=not at all) to 7 (=very much) [Dalbert, 1992].

3.6.2 Task perceptions.

As a manipulation check if ego-depletion was successfully induced, participants were instructed to rate the counting task on seven-point Likert scales, from 1 (=not at all) to 7 (=very much), in terms of fatigue, difficulty and effort [Webb and Sheeran, 2003].

3.6.3 Impulsiveness.

The short German version of the Barratt Impulsiveness Scale (BIS-15) was used, which is one of the most common scales to measure impulsive behavior as a trait [Spinella, 2007; Meule et al., 2011]. The Barrat Impulsiveness Scale focuses on behaviors like absence of planning, spontaneity when it comes to making decisions and generally acting without foresight and forethought [de Ridder et al., 2012]. The BIS-15 consists of three factors which are non-planning, motor and attentional impulsivity and each factor consists of five items which can be rated on a four point scale ranging from 1 (=never) to 4 (=always). Statements for non-planning include “I plan tasks carefully”, for attention impulsivity “I am restless at lectures or talks” and for motor impulsivity “I say things without thinking” [Spinella, 2007; Meule et al., 2011].

3.6.4 Dietary Restraint.

The German translation of the sub-scale for restrained eating of the Dutch Eating Behavior Questionnaire was used [Van Strien et al., 1986] consisting of 10 items which specifically targets restrained eaters with questions like “When you have put on weight, do you eat less than you usually do?” or “Do you deliberately eat less in order not to
become heavier?”. These questions can be answered on a five-point likert scale ranging from 1 (=never)” to 5 (=very often) [Van Strien et al., 1986].

3.6.5 Perceived Self-Regulatory Success in Dieting Scale.

The PSRS functions as a tool to differentiate between successful and non-successful restraint eaters and consists of three questions like “How successful are you in watching your weight?”. These questions can be rated on a seven-point likert scale from 1 (=not successful) to 7 (=very successful) [Fishbach et al., 2003; Meule et al., 2012].

3.6.6 Assessment of hunger and liking of walnuts.

To measure hunger before and after the experiment a visual analogue scale with a length of 100mm was used with four anchor points which were “no hunger at all”, “hungry”, “very hungry”, “extremely hungry” [Stubbs et al., 2000]. For the measurement of liking of walnuts a visual analogue scale with three anchor points was used which were “not at all “, “either…or”, “very much” similar to a prior study [Missbach, 2012].

3.6.7 Body Mass Index.

Additionally also questions about weight and height were included in order to calculate the body mass index (BMI) which is defined as the body mass of an individual divided by the square of the height. The value is usually given in units of kg/m² and the BMI is widely used for an easy assessment of how much the body weight departs from what is normal for a person with the same height [Elmadfa and Leitzmann, 2004].

3.6.8 Quantity of consumed walnuts.

As the most important dependent variable served the consumed quantity of all four walnut brands which were assessed by weighing the walnuts before and after the experiment with a standard scale with three decimals places.
3.7 Main-Hypotheses.

Main-Hypothesis I

*Does mental imagery with walnuts influence subsequent consumption of walnuts when individuals are in a state of low ego-depletion?*

- H0: There is no difference in walnut consumption between low-depleted participants who imagined eating walnuts (EL-MIW) compared to low-depleted participants in the corresponding control condition, who imagined putting a coin into the laundry machine (EL-MIC).

- H1: There is a difference in walnut consumption between low-depleted participants who imagined eating walnuts (EL-MIW) compared to low-depleted participants in the corresponding control condition, who imagined putting a coin into the laundry machine (EL-MIC).

Main-Hypothesis II

*Does mental imagery with walnuts influence subsequent consumption of walnuts when individuals are in a state of high ego-depletion?*

- H0: There is no difference in walnut consumption between high-depleted participants who imagined eating walnuts (EH-MIW) compared to high-depleted participants in the corresponding control condition, who imagined putting a coin into the laundry machine (EH-MIC).

- H1: There is a difference in walnut consumption between high-depleted participants who imagined eating walnuts (EH-MIW) compared to high-depleted participants in the corresponding control condition, who imagined putting a coin into the laundry machine (EH-MIC).
3.8 Sub-Hypotheses.

Sub-Hypothesis I:

*Does the state of hunger influence subsequent consumption of walnuts?*

- H0: Hunger scores do not influence consumption of walnuts.
- H1: Hunger scores influence consumption of walnuts.

Sub-Hypothesis II:

*Does liking of walnuts prior to testing influence subsequent consumption of walnuts?*

- H0: Liking scores do not influence consumption of walnuts.
- H1: Liking scores influence consumption of walnuts.

Sub-Hypothesis III:

*Does the body mass index influence subsequent consumption of walnuts?*

- H0: BMI scores do not influence consumption of walnuts.
- H1: BMI scores influence consumption of walnuts.

Sub-Hypothesis IV:

*Does dietary restraint (measured by DEBQ-RE) influence subsequent consumption of walnuts?*

- H0: DEBQ-RE scores do not influence consumption of walnuts.
- H1: DEBQ-RE scores influence consumption of walnuts.

Sub-Hypothesis V:

*Does Perceived Self-Regulatory Success in Dieting influence subsequent consumption of walnuts?*

- H0: PSRS-scores do not influence consumption of walnuts.
- H1: PSRS-scores influence consumption of walnuts.
Sub-Hypothesis VI:

*Does Impulsiveness influence subsequent consumption of walnuts?*

- $H_0$: BIS-15-scores do not influence consumption of walnuts.
- $H_1$: BIS-15-scores influence consumption of walnuts.

Sub-Hypothesis VII:

*Does mood influence subsequent consumption of walnuts?*

- $H_0$: Mood-scores do not influence consumption of walnuts.
- $H_1$: Mood-scores influence consumption of walnuts.
4 Results.

4.1 Descriptive statistics.

4.1.1 Sample sizes.

In sum, ninety females were recruited to participate in the experiment. Three participants had to be excluded from the study because they failed the mental imagery check by answering the control question if they had conducted the imagery task with “no”. One participant had to be excluded because she had thrown the nuts after the taste-test into the trash and therefore it was not possible to examine the consumed amount of walnuts. So in total the data of 86 participants were included into the statistical analysis which was computed by using IBM SPSS Statistics 20. The significance level was set at $\alpha = 0.05$.

Table 1: Sample sizes of the four different groups

<table>
<thead>
<tr>
<th>Participants</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Ego-Depletion High &amp; Mental Imagery Nuts</td>
<td>EH-MIW 22 (25.6%)</td>
</tr>
<tr>
<td>Ego-Depletion High &amp; Mental Imagery Coins</td>
<td>EH-MIC 22 (25.6%)</td>
</tr>
<tr>
<td>Ego-Depletion Low &amp; Mental Imagery Nuts</td>
<td>EL-MIW 21 (24.4%)</td>
</tr>
<tr>
<td>Ego-Depletion Low &amp; Mental Imagery Coins</td>
<td>EL-MIC 21 (24.4%)</td>
</tr>
</tbody>
</table>

Table 2: Sample sizes of the two Ego-Depletion groups

<table>
<thead>
<tr>
<th>Participants</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Ego-Depletion - High</td>
<td>EH 44 (51.2%)</td>
</tr>
<tr>
<td>Ego-Depletion - Low</td>
<td>EL 42 (48.8%)</td>
</tr>
</tbody>
</table>

Table 3: Sample sizes of the two Mental Imagery groups

<table>
<thead>
<tr>
<th>Participants</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Mental Imagery - Walnuts</td>
<td>MIW 42 (48.8%)</td>
</tr>
<tr>
<td>Mental Imagery - Coins</td>
<td>MIC 44 (51.2%)</td>
</tr>
</tbody>
</table>
4.1.2 Age.

Only females aged between 18 and 35 years were recruited to take part in the study. The mean age was 24.52 years (SD=3.18) with the youngest participant being 19 years old and the oldest one aged 35.

The Boxplot shows that 50% are between 22 and 26 years old with a median of 24 years. The data were not normally distributed (Kolmogorov-Smirnov: $p < 0.05$).

*Figure 9: Distribution of age among all participants (boxplot)*

4.1.3 Body Mass Index.

As mentioned earlier all participants were asked to state their height and weight, which was used to calculate the Body Mass Index (BMI) by using following formula [Elmadfa and Leitzmann, 2004]:

$$BMI = \frac{\text{bodyweight}(kg)}{(\text{height}(m))^2}$$
The results show that the mean BMI was 21.38 kg/m² (SD=2.66). The Boxplot shows that 50% of all participants scored between 19.54 and 22.76 kg/m² with a median of 20.85 kg/m². The data were not normally distributed (Kolmogorov-Smirnov: p < 0.05). For further clarification following BMI-classification for women was used to determine under-, normal-, overweight and obesity [Elmadfa and Leitzmann, 2004]. Results showed that 73.3 percent of all participants were of normal weight (N=63), while 12.8 percent were either classified to be underweight (N=11) or to be overweight (N=11). Only one female had a BMI score higher than 30 kg/m² and therefore was categorized as being obese.

Table 4: BMI classification among all participants

<table>
<thead>
<tr>
<th>BMI (kg/m²)</th>
<th>Number of participants</th>
<th>Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 19</td>
<td>11</td>
<td>underweight</td>
</tr>
<tr>
<td>19-24</td>
<td>63</td>
<td>normal</td>
</tr>
<tr>
<td>24-30</td>
<td>11</td>
<td>overweight</td>
</tr>
<tr>
<td>&gt;30</td>
<td>1</td>
<td>obese</td>
</tr>
</tbody>
</table>
4.1.4 **Time of last meal intake.**

Participants were instructed to sustain from eating for about three hours prior to the experiment. Results show that all individuals followed this instruction with a mean time of 4.78 hours (SD=3.56), a minimum of 3 hours and a maximum of 17 hours. The data were not normally distributed (Kolmogorov-Smirnov: p < 0.05).

4.1.5 **Time of experiment.**

The experiments were conducted between 01.02.2014 and 03.03.2014. The time of day varied between 0900 at the earliest and 1800 at latest. About 54.7% (N=47) of all subjects were tested between 1200 and 1500 while 26.7 % (N=23) participated before lunchtime (1200) and 18.6. % after 1500 (N=16).

*Figure 11: Time of experiment (bar graph)*
4.2 Preliminary analysis.

4.2.1 Manipulation Check – Ego-Depletion.

In order to make sure ego-depletion was successfully induced, participants had to rate the counting task on seven-point likert scales which are ranging from 1 (=not at all) to 7 (=very much) in terms of fatigue, difficulty and effort [Webb and Sheeran, 2003]. To test the internal consistency of the task perception Cronbach’s Alpha test on reliability over the three items was used. Usually a score between 0.7 and 0.9 is considered to be of good internal consistency.

Cronbach’s $\alpha = 0.865$

*Figure 12: Depletion Points in EH and EL (boxplot)*

The boxplot displays that 50% of all subjects in the high ego-depletion groups rated the counting task between 13 and 16.75 points (median = 15 points) compared to 50% of all participants in the low ego-depletion groups who assigned only between 4.75 and 8.25 points (median = 6.5 points). Furthermore an unpaired t-test was performed (Kolmogorov-Smirnov for both conditions $p > 0.05$).
Table 5: Comparison depletion points EH vs EL

<table>
<thead>
<tr>
<th>EH vs. EL</th>
<th>Mean scores depletion check (points)</th>
</tr>
</thead>
<tbody>
<tr>
<td>EH</td>
<td>14.75 (SD=2.70)</td>
</tr>
<tr>
<td>EL</td>
<td>6.60 (SD=2.35)</td>
</tr>
</tbody>
</table>

Results show that there is a significant difference ($p = 0.000$) in how participants rated the counting task between the depletion groups (high vs. low) indicating that the depleting task was successful.

4.2.2 Manipulation Check – Mood.

Positive and negative emotional states were measured to make sure that any effects of ego-depletion are not caused by changes in the mood. The German version of the profile of mood states was used with 19 different items belonging either to grief (n=3), desperation (n=3), rage (n=3), tiredness (n=4) or positive mood (n=6) [Dalbert, 1992].

Table 6: Cronbach’s Alpha for mood

<table>
<thead>
<tr>
<th>Mood</th>
<th>Items</th>
<th>Cronbach’s $\alpha$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rage</td>
<td>3</td>
<td>0.765</td>
</tr>
<tr>
<td>Grief</td>
<td>3</td>
<td>0.861</td>
</tr>
<tr>
<td>Desperation</td>
<td>3</td>
<td>0.812</td>
</tr>
<tr>
<td>Tiredness</td>
<td>4</td>
<td>0.913</td>
</tr>
<tr>
<td>Positive mood</td>
<td>6</td>
<td>0.891</td>
</tr>
</tbody>
</table>

One-way ANOVA was performed to see if there are any differences in mood between individuals in the high ego-depletion condition and low ego-depletion condition. Results show no significant differences ($p > 0.05$) (before and after Bonferroni correction) in mood between the two ego-depletion groups (high vs. low) suggesting that the counting task, to induce ego-depletion, did not result in any significant mood changes. Therefore all other possible effects caused by ego-depletion cannot be attributed to variances in mood.
4.3 Main analysis.

4.3.1 Consumption of walnuts.

Figure 13: Consumed walnuts among all participants (histogram)

Figure 14: Consumed walnuts among all participants (boxplot)
The mean intake of walnuts among all participants was 35.63g (SD=13.61). The boxplot reveals that 50% of all individuals ate between 25.99 and 43.09g of walnuts with a median of 33.39g.

4.3.2 Consumption of walnuts within the four groups.

*Figure 15: Consumed walnuts within the four groups (boxplot)*

The boxplots of the four groups reveal that 50% of all individuals in the EL-MIC group ate between 28.74 and 43.1g walnuts (median = 37.49g) while 50% of all participants in the EL-MIW group ate between 23.11 and 34.30g (median = 29.69g).

In comparison 50% of all participants in the EH-MIC group ate between 25.45 and 57.68g (median = 36.49g) and 50% in the EH-MIW group between 27.28 and 46.4g (median = 35.35g). Data in all the groups were normally distributed (Kolmogorov-Smirnov: p> 0.05) which is why unpaired t-tests were executed between EH-MIW and EH-MIC as well as between EL-MIW and EL-MIC.
Table 7: Comparison consumed walnuts between the four groups

<table>
<thead>
<tr>
<th>Interventions</th>
<th>Mean intake of walnuts in g</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>EH-MIW</td>
<td>37.49 (SD=13.39)</td>
<td>p=0.867</td>
</tr>
<tr>
<td>EH-MIC</td>
<td>38.31 (SD=18.34)</td>
<td></td>
</tr>
<tr>
<td>EL-MIW</td>
<td>29.61 (SD=8.91)</td>
<td>p=0.022</td>
</tr>
<tr>
<td>EL-MIC</td>
<td>36.90 (SD=10.73)</td>
<td></td>
</tr>
</tbody>
</table>

Results show that low-ego-depleted individuals, who repeatedly imagined eating walnuts, consumed significantly less walnuts (after Bonferroni correction) in the subsequent taste test compared to their low ego-depleted counterparts, who repetitively imagined putting a coin into a laundry machine.

In regards to the main hypothesis I of this study which stated “Does mental imagery with walnuts influence subsequent consumption of walnuts when individuals are in a state of low ego-depletion?” the null hypothesis has to be rejected.

There is a significant difference in walnut consumption between low-depleted participants who imagined eating walnuts (EL-MIW) compared to low-depleted participants in the corresponding control condition, who imagined putting a coin into the laundry machine (EL-MIC).

Furthermore results also demonstrate that there is no significant difference in walnuts consumption between those who imagined eating walnuts compared to the control condition when all individuals were in a state of high ego-depletion.

As to the main hypothesis II which stated “Does mental imagery with walnuts influence subsequent consumption of walnuts when individuals are in a state of high ego-depletion?” the null hypothesis (H0) has to be accepted.

There is no significant difference in walnut consumption between high-depleted participants who imagined eating walnuts (EH-MIW) compared to high-depleted participants in the corresponding control condition (before and after Bonferroni correction), who imagined putting a coin into the laundry machine (EH-MIC).

Results will be thoroughly discussed in chapter 5.
4.3.3 Consumption of walnuts within the depletion & the mental imagery groups.

*Figure 16: Consumed walnuts within the depletion groups (boxplot)*

The boxplots of the ego-depletion groups (high vs. low) show that 50% of all highly ego-depleted individuals, independent of mental imagery condition, ate between 26.29 and 50.6g (median = 36.16g).

In contrast 50% of all low ego-depleted participants only ate between 24.99 and 41.64g (median = 32.68g) which exemplifies the wide range of the data in the high ego-depletion groups.
Figure 17: Consumed walnuts within the mental imagery groups (boxplot)

The boxplots of the mental imagery groups show that 50% of all participants, who imagined eating walnuts, independent of state of ego-depletion, ate between 25.71 and 42.40g (median = 32.34g).

As opposed to this 50% of all subjects who were assigned to the control group and imagined putting 50cent coins into a laundry automate, ate between 26.82 and 43.79g (median = 37.46g).

Results show no significant differences between the ego-depletion groups (low vs. high) as well as between the mental imagery groups (walnuts vs. coins).
4.3.4 Possible influences on walnut consumption.

To determine if any other factors influence subsequent consumption of walnuts among all individuals and between EL-MIC and EL-MIW linear regression analysis was performed.

Dependent variable was the amount of walnuts consumed during the taste-test and the predictor variables were liking of walnuts before the experiment, hunger before the experiment, BMI-scores, DEBQ-RE-scores (Cronbach’s $\alpha = 0.911$), mood-scores and BIS-15-scores (overall Cronbach’s $\alpha = 0.780$).

Results show that walnut consumption was not influenced by any of those factors ($p > 0.05$) and therefore all alternative Sub-Hypotheses (I-VII) should be rejected and the null hypotheses (H0) have to be accepted.

Furthermore there was no significant difference between liking of walnuts before and after the taste-test ($p > 0.05$) and also no significant difference between hunger before and after the taste-test ($p > 0.05$).
5 Discussion.

5.1 Conclusion.

In the present study a mental imagery paradigm was conducted among high ego-depleted and low ego-depleted females who participated in a subsequent camouflaged taste-test of walnuts. The consumed amount of walnuts served as the dependent variable.

5.1.1 Preliminary analysis.

Regarding the preliminary analysis it has to be stated that there was a significant difference in perceived fatigue, effort and difficulty between the high and low-ego-depletion task. According to previous studies, this result indicates that ego-depletion was successfully induced [Hagger et al., 2010; Hagger et al., 2013]. Additionally there was no significant difference in various kinds of mood between the two groups which is in line with previous research [Alberts et al., 2007; Hagger et al., 2010].

5.1.2 Sub-Hypothesis I-VII.

Results demonstrate that the null hypothesis for every single sub-hypothesis can be accepted.

Therefore walnut consumption was not influenced by:

- mood states (either positive or negative)
- restrained eating
- perceived self-regulatory success in dieting
- trait impulsiveness
- BMI
- hunger
- liking of walnuts
Moreover there was also no difference in liking of walnuts before and after the experiment which is consistent with previous findings regarding habituation [Morewedge et al., 2010; Missbach, 2012].

It should also be mentioned that trait impulsiveness, measured with the BIS-15 scale, did neither influence the intake of walnuts nor correlated with the rating of the manipulation task in terms of perceived fatigue, effort and difficulty. This outcome indicates that ego-depletion was independent of being low in self-control and will be further discussed in context of the process model of ego-depletion.

5.1.3 Main Hypotheses.

5.1.3.1 Main Hypothesis I.

Results show that there is a significant difference in walnut intake between the mental imagery condition with walnuts and the mental imagery condition with coins - but only when both groups are in a state of low ego-depletion.

In other words: imagining eating walnuts led to a habituation effect which caused a significant decrease in walnut consumption as long cognitive resources were intact.

This outcome is in line with previous research [Morewedge et al., 2010; Missbach, 2012] and extends those findings in two ways:

First, mental imagining was successful with only eighteen repetitions compared to thirty-six [Missbach, 2012] and thirty [Morewedge et al., 2010].

Second, it was established that the decrease in subsequent food intake is also possible with an allegedly healthy food (walnuts) and therefore emphasizes the role of the habituation effect.

There are two possible reasons why eighteen repetitions were enough to lead to a decrease in walnut consumption. Both explanations are due to the fact that all participants were tested individually:
1. Because of the specific experimental setting it was possible to explicitly explain and elaborate the task and therefore implementation success could be increased while misconceptions were avoided.

2. Also because of the individual testing procedure subjects were not distracted by other participants or potential interruptions and were therefore able to focus on the task.

5.1.3.2 Main Hypothesis II.

On the other hand results also reveal no significant difference in walnut consumption between the two mental imagery conditions when participants were highly ego-depleted.

*This result indicates that the process of mental imagery is not successful when cognitive resources are scarce:*

In the context of the strength/resource model of self-control the findings are in line with previous studies showing that after exercising self-control in a first task performance will be weakened on a second self-control task [Baumeister et al., 2007].

Willpower is essential for resisting the temptation to quit during the high-depletion counting task and willpower is also necessary to imagine repeatedly eating walnuts. Therefore it is plausible that the first task reduced the energy resources needed for self-control.

It is also rather doubtful that the state of ego-depletion disrupted the process of habituation which is the simplest form of implicit learning and often occurs without even noticing it [Schacter et al., 2009].

It is much more reasonable that the participants in the high ego-depletion condition were unable to fully perform the mental imagery task because of the cognitive impairment caused by the difficult counting task. This assumption would also be consistent with the balance model of self-regulation displayed in Figure 4 (page 36 in this thesis).

The model suggests that resource depletion would impair functioning of the prefrontal cortex and therefore cause self-regulatory failure [Heatherton and Wagner, 2011].
Another common assumption is that people high in self-control would be less vulnerable to ego-depletion which therefore implies that such individuals would have a higher resource capacity at their disposal [Hagger et al., 2010].

It would be consistent with the resource model that participants who scored high in trait self-control would have a higher self-control capacity and therefore be less prone to ego-depletion [Hagger et al., 2010]. However, the findings of the present study reveal that low self-control (measured as high trait impulsiveness) did not correlate with the perceived levels of effort, fatigue and difficulty of the first self-control task. In other words: participants who scored high in impulsiveness (therefore low in self-control) were not more susceptible to ego-depletion as the resource model of self-control would have predicted.

One intriguing explanation could be that the observed ego-depletion effects were neither caused nor mediated by a reduction of energy resources. As already stated the biggest issue with the resource model of self-control is that the resource has not been discovered yet [Inzlicht et al., 2014].

There is also general doubt regarding the existence of this energy resource because studies have shown that the ego-depletion effect can be easily counteracted by believing willpower is not limited [Job et al., 2010] or just by manipulated motivation [Muraven and Slessareva, 2003]. Some studies have also demonstrated that induction of positive mood or self-affirmation are useful to avoid ego-depletion [Tice et al., 2007; Schmeichel and Vohs, 2009].

It seems unlikely that such implementations are able to refill an exhausted source, which is why some researchers started to question the resource metaphor for elaborating self-control and self-control failure [Inzlicht et al., 2014].

Inzlicht and Schmeichel propose a so called “process model of ego-depletion” [Inzlicht et al., 2014] instead of the resource model. They argue that a diminished performance on the second task is not caused by the depletion of some unknown energy resource but rather due a change in “motivational orientation” and “attentional focus” [Inzlicht and Schmeichel, 2012]. This change in motivation occurs namely away from restraining any
wishes or urges and to allowing them [Inzlicht and Schmeichel, 2012]. In plain words: after exercising self-control people are more attracted to things which are more satisfying and pleasurable to them [Inzlicht and Schmeichel, 2012].

**Figure 18: The imbalance of motivations [Inzlicht et al., 2014]**

As displayed in Figures 18 and 19 engaging in “have-to goals, labor and exploitation” leads to a disbalance or discrepancy of motivations [Inzlicht et al., 2014].

**Figure 19: Process model of ego-depletion [Inzlicht et al., 2014]**
The process model of ego-depletion implies that depleted individuals just do not feel the need for controlling themselves rather than being not able to do so [Inzlicht et al., 2014].

Such a behavior also seems plausible from an evolutionary perspective. A flexible shift between cognitive effort and cognitive relaxation can help to stay focused on a task but also permits to detach from it and to look for alternatives which could have more rewarding properties [Inzlicht et al., 2014].

This proposition would be similar to the “motivational control theory of fatigue” [Hockey, 1997] which suggests that not loss of energy but a change of goals mediates the effects of fatigue [Inzlicht et al., 2014].

In the light of this new concept it is plausible that participants in the present study were not cognitively depleted but rather experienced such a shift away from “have-to” to “want-to” goals [Inzlicht et al., 2014].

After having engaged in the high ego-depletion task (have-to) it is possible that due to a priority-change motivation and attention for the mental imagery paradigm were weakened, which would have been another “have-to” task [Inzlicht et al., 2014].

In this context it has been argued that a motivational mediated ego-depletion effect could also be caused by experimenter demand. This would explain the poor performance on the second task (mental imagery) as a result of participants believing they have pleased the wishes/demands of the experimenter after the first task (counting) [Hagger et al., 2010].

Nevertheless studies have shown that ego-depletion effects could also be replicated when each task was presented by various experimenters [Richeson et al., 2005; Vohs et al., 2008].

However, it is probable that, after the difficult counting task (have-to), participants thought they were allowed to take a break because they already had worked hard and had done their part for the study independently of the experimenter [Inzlicht and Schmeichel, 2012].
Therefore the subjects did not engage in the mental imagery task with the same effort as in the counting task. Consequently no habituation process came into action and therefore the intake of walnuts was not reduced.

On the other hand the low ego-depletion task was rather simple and therefore no switch from “have-to” to “want-to” goals [Inzlicht et al., 2014] was activated before the mental imagery task. Thus mental imagery was successfully accomplished by enabling habituation and leading to a decrease in walnut consumption.

In conclusion, the current findings demonstrate that mental imagery is capable of reducing food consumption in the short-term, but fails doing so after a cognitive effortful task that required self-control.

According to Morewedge et al. the implementation of mental imagery techniques could be important to “develop more effective interventions in order to achieve a reduction in cravings for unhealthy foods” [Morewedge et al., 2010].

With the findings of the present study this proposition has been seriously challenged. Only a short period of unpleasant cognitive work was sufficient enough to offset the beneficial effects either by diminishing a potential energy resource or by causing a change in motivation.

Nevertheless there are several limitations in the present study that should be considered for further research.
5.1.4 Limitations.

First, the study sample was rather small and therefore a larger size would have offered a greater statistical power.

Second, the sample consisted only of young non-clinical female university students. Due to such a non-representative sample the findings should not be generalized to non-university women, men or especially clinical population groups.

Third, it should also be addressed that the sample included almost exclusively students from nutritional science. Those may have a higher interest in health issues which could be the reason why most of the participants were of normal-weight and only one participant was classified as obese. It is possible that truly obese individuals would have responded in a different way compared to leaner individuals.

Fourth, the initial announcement of a taste-test with walnuts could have led to a selection bias so that women, who crave more for sugary foods, perhaps refrained from participating. However, it was specifically intended to test the mental imagery paradigm with an allegedly healthy food.

Fifth, the study also included self-report questionnaires. Hence there is a possibility of intentional false-reporting (e.g. scales of impulsiveness and dietary restraint) and underreporting (e.g. bodyweight).

Sixth, mood was only assessed once after the first self-control task and therefore no initial baseline was available. It would have been better to assess the states of mood before the experiment and after the counting task in order to clarify if the null findings regarding mood were maybe an accidental result caused by the randomized allocation to the intervention groups. Although this was originally considered to do so, it was eventually decided against it mainly due to time reasons.

Seventh, the central limitation of this study is that there was no manipulation check in terms of fatigue, effort and difficulty after the mental imagery task. Such a questionnaire would have been helpful to clarify the amount of perceived cognitive effort and therefore been a clue if the subjects just did not want to imagine
walnuts (e.g. because of lack of motivation) or tried but failed doing so (e.g. because a potential energy resource was depleted).

5.2 Summary.

5.2.1 Background.

Recent research has shown that repetitively thinking about eating a certain food will lead to a stimulus-specific habituation effect and consequently cause a decrease in consumption of the imagined food in a subsequent taste-test. Furthermore it has been proposed that such mental imagery procedures would be useful strategies to cope with urges to overeat especially in the context of the obesogenic environment. However, in the present thesis it was hypothesized that the implementation of mental imagery techniques would strongly depend on one’s cognitive capacity and especially on the capability to exercise self-control to withstand the urge to quit the task. Essentially, self-control or self-discipline can be defined as the capability to inhibit short-term desires with the purpose to attain long-term goals. According to the resource model humans’ capability to control themselves is limited. After the exertion of self-control a state of ego-depletion will follow and temporarily impair performance on any other tasks that may require self-control. In this context the aim of this thesis was to investigate if mental imagery depends on the same cognitive resources as self-control by replicating the habituation effect both in a state of high and low ego-depletion in a non-clinical study sample. Moreover this thesis provides an extensive overview of current concepts of self-control and common strategies to cope with the urge to overeat.

5.2.2 Methods.

Eighty-six female university students were recruited to participate in a camouflaged taste-test with walnuts. They were blinded to the actual objective of the study and were instructed to refrain from eating at least three hours before the experiment. Subjects were randomly assigned to a 2 (Ego-Depletion: high vs. low) x 2 (Mental Imagery: walnuts vs. coins) between-subjects design which was implemented in the form of a classical dual task procedure. First, a counting task was applied in two different variations of difficulty in order to induce a state of high and low ego-depletion. Second,
the mental imagery paradigm was performed either by thinking about eating walnuts (18 repetitions) or imagining putting a 50 cent coin into a laundry automate (18 repetitions). Unbeknownst to the participants, walnuts were weighed before and after the subsequent taste-test and so the amount of consumed walnuts served as the main dependent variable in this experiment while the qualitative results of the taste-test were not further analyzed.

5.2.3 Results.

Subjects in the mental imagery condition with walnuts ate less compared to the mental imagery condition with coins (p=0.022) but only when both groups were in a state of low ego-depletion. On the other hand there was no significant difference in walnut consumption between the two mental imagery groups when all subjects were in a state of high ego-depletion. Moreover walnut intake was not influenced by hunger, liking of walnuts, BMI, dietary restraint, trait impulsiveness or mood.

5.2.4 Conclusion.

This thesis provides evidence that repeatedly imagining food intake causes a reduction of subsequent consumption but only when cognitive resources are intact. It extends previous findings by demonstrating that the process of mental imagery is not successful in reducing food intake when subjects are in a state of cognitive impairment. These results are in line with current research on ego-depletion which proposes that after cognitive labor (counting task) people experience a temporarily reduction in motivation and attention for another potentially unpleasant task (mental imagery task). Consequently no habituation process came into action and therefore the intake of walnuts was not reduced.
5.3 Zusammenfassung.

5.3.1 Hintergrund.

Neueste Studien haben gezeigt, dass eine wiederholte bildliche Vorstellung (mental imagery) des Essvorgangs einen Habituationseffekt bewirkt und dadurch die Aufnahme des vorgestellten Lebensmittel reduziert werden kann. Weiters wurde argumentiert, dass die Anwendung solcher „mental imagery“-Verfahren gerade im Hinblick auf die „obesogene“ Umwelt eine mögliche Bewältigungsstrategie für Heißhungerattacken wäre. In der vorliegenden Arbeit wurde die Theorie aufgestellt, dass die Umsetzung solcher Verfahren stark von der individuellen kognitiven Leistungsfähigkeit beziehungsweise der Befähigung zur Selbstkontrolle abhängen könnte.


5.3.2 Methoden.

Insgesamt nahmen sechsundachtzig Studentinnen an der Studie teil, welche als Akzeptanztest von Walnüssen getarnt wurde. Alle Teilnehmerinnen wurden gebeten mindestens drei Stunden vor dem Experiment nichts mehr zu essen. Es erfolgte eine randomisierte Zuteilung in eine der vier Gruppen des 2 (Ego-Depletion: stark vs. gering) x 2 (Mental Imagery: Walnüsse vs. Münzen) „between subject“ Designs, welches als klassisches „Dual Task“ Prozedere präsentiert wurde. Dieses umfasste eine
mathematische Aufgabe in zwei verschiedenen Schwierigkeitsstufen, um sowohl einen starken als auch geringen Zustand der Ego-Depletion zu erzielen. Die zweite Aufgabe bestand aus dem „mental imagery“ Paradigma, das ebenfalls in zwei Variationen präsentiert wurde. Während sich eine Gruppe (Mental Imagery: Walnüsse) achtzehn mal vorstellte Walnüsse zu essen, stellte sich die andere Gruppe (Mental Imagery: Münzen) ebenfalls achtzehn mal vor 50 Cent Münzen in einen Waschautomat einzuwerfen. Danach nahmen alle Teilnehmerinnen an einem Akzeptanztest von Walnüssen teil und die verzehrte Menge diente als abhängige Variable dieser Studie.

5.3.3 Ergebnisse.

Jene Probandinnen, welche sich vorgestellt hatten Walnüsse zu essen, konsumierten während des Akzeptanztests weniger im Vergleich zu jenen, die sich Münzen vorstellten (p=0.022). Dies konnte allerdings nur in einem Zustand geringer Ego-Depletion beobachtet werden. Es konnte kein signifikanter Unterschied hinsichtlich des Walnussverzehrs zwischen den zwei Mental Imagery Gruppen festgestellt werden, wenn beide im Zustand starker Ego-Depletion waren. Außerdem war der Verzehr in allen Gruppen unbeeinflusst von Hunger, gezügeltem Essverhalten, Impulsivität, BMI oder aktueller Stimmungslage.

5.3.4 Fazit.

6 Appendix.

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"Ich habe mich bemüht, sämtliche Inhaber der Bildrechte ausfindig zu machen und ihre Zustimmung zur Verwendung der Bilder in dieser Arbeit eingeholt. Sollte dennoch eine Urheberrechtsverletzung bekannt werden, ersuche ich um Meldung bei mir."

6.2 Attachments.

6.2.1 Questionnaires.

6.2.1.1 Dutch Eating Behavior Questionnaire – Subscale for restrained eating


<table>
<thead>
<tr>
<th>Bitte lesen Sie gründlich alle nachfolgenden Fragen und beantworten Sie diese sorgfältig.</th>
<th>sehr oft</th>
<th>oft</th>
<th>manchmal</th>
<th>selten</th>
<th>niemals</th>
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<tr>
<td>Achten Sie genau auf das, was Sie essen?</td>
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<td>Essen Sie bewusst weniger, um nicht zuzunehmen?</td>
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<td>Wenn Sie in letzter Zeit zugenommen haben, essen Sie dann weniger als sonst?</td>
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<td>Wenn Sie an einem Tag zu viel gegessen haben, essen Sie dann am nächsten Tag weniger?</td>
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<td>Berücksichtigen Sie Ihr Gewicht bei der Entscheidung, was Sie essen?</td>
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<td>Wie oft versuchen Sie zwischen den Mahlzeiten nicht zu essen, weil Sie auf Ihr Gewicht achten?</td>
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<tr>
<td>Wie oft versuchen Sie am Abend nichts zu essen, weil Sie auf Ihr Gewicht achten?</td>
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<tr>
<td>Versuchen Sie während der Mahlzeiten weniger zu essen als Sie gerne essen würden?</td>
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Wie oft lehnen Sie Speisen oder Getränke ab, weil Sie um Ihr Gewicht besorgt sind?  
Essen Sie bewusst schlankmachende Speisen?

6.2.1.2 Perceived Self-Regulatory Success in Dieting Scale.

German version retrieved (01/14) from:  
http://adrianmeule.files.wordpress.com/2013/05/psrs.pdf

Bitte beantworten Sie die Fragen auf einer Skala von 1 (=überhaupt nicht gut) bis 7 (=sehr gut)

Wie gut gelingt es Ihnen abzunehmen?  
Wie gut gelingt es Ihnen auf Ihr Gewicht zu achten?

Bitte beantworten Sie die Frage auf einer Skala von 1 (=überhaupt nicht schwierig) bis 7 (=sehr schwierig)

Wie schwierig finden Sie es in Form zu bleiben?

6.2.1.3 Profile of mood states (Aktuelle Stimmungsskala).

German version retrieved (01/14) from:  
www.erzwiss.uni-halle.de/gliederung/paed/pppsych/sdasts.pdf

Wie würden Sie Ihren momentanen Gefühlzustand beschreiben?

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<td>hoffnungslos</td>
<td>verärgert</td>
<td>frohgemut</td>
<td>entmutigt</td>
<td>müde</td>
<td>erschöpft</td>
<td>fröhlich</td>
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<tr>
<td>heiter</td>
<td>verzweifelt</td>
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<td>entkräftet</td>
<td>lustig</td>
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### 6.2.1.4 Manipulation Check – Ego-Depletion and Mental Imagery.

<table>
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<tr>
<th>Wie empfanden Sie gerade von Ihnen absolvierten Aufgabe (Rückwärtszählen):</th>
<th>sehr stark</th>
<th>stark</th>
<th>ziemlich</th>
<th>etwas</th>
<th>schwach</th>
<th>sehr schwach</th>
<th>überhaupt nicht</th>
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Haben Sie sich vorhin wirklich das vorgestellt worum wir Sie gebeten haben?

☐ ja  ☐ nein
6.2.1.5 Barratt Impulsiveness Scale (BIS-15).

German version retrieved (01/14) from:
http://adrianmeule.files.wordpress.com/2013/05/bis-15.pdf

Bitte lesen Sie sorgfältig alle nachfolgenden Aussagen und entscheiden Sie in welchem Ausmaß diese auf Sie zutreffen.

<table>
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<tr>
<th>Statement</th>
<th>fast immer/immer</th>
<th>oft</th>
<th>gelegentlich</th>
<th>selten/nie</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ich plane meine Vorhaben gründlich.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ich mache häufig Dinge ohne vorher darüber nachzudenken.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ich bin unaufmerksam.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ich kann mich gut konzentrieren.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ich sichere mich im Leben in allen Dingen ab.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ich rutsche bei Spielen oder Vorträgen oft hin und her.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ich denke gründlich nach.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ich plane für meine berufliche Sicherheit.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ich sage Dinge ohne darüber nachzudenken.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ich handele spontan.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mir wird beim Lösen von Denkaufgaben schnell langweilig.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ich handele gerne aus dem Moment heraus.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ich kaufe Sachen ganz spontan.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ich werde bei Vorlesungen oder Vorträgen schnell unruhig.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ich plane für die Zukunft.</td>
<td></td>
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</tr>
</tbody>
</table>
6.2.1.6 Taste-test of walnuts.

**Akzeptanztest:**

Bei diesem Test sollen geschmackliche, geruchliche und texturale Eigenschaften von Walnusskernen vier verschiedener Hersteller bewertet und verglichen werden.

Bitte lassen Sie sich ruhig Zeit.

Für eine exakte sensorische Prüfung ist es außerdem wichtig, dass Sie von allen vier Produkten ausreichend essen.

Es dürfen unbegrenzt Walnüsse verzehrt werden.

<table>
<thead>
<tr>
<th>Wie bewerten Sie den Geschmack:</th>
<th>ausgezeichnet</th>
<th>eher gut</th>
<th>passabel</th>
<th>weder/noch</th>
<th>eher nicht gut</th>
<th>überhaupt nicht gut</th>
</tr>
</thead>
<tbody>
<tr>
<td>Produkt A</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Produkt B</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Produkt C</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Produkt D</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Wie bewerten Sie die Festigkeit:</th>
<th>ausgezeichnet</th>
<th>eher gut</th>
<th>passabel</th>
<th>weder/noch</th>
<th>eher nicht gut</th>
<th>überhaupt nicht gut</th>
</tr>
</thead>
<tbody>
<tr>
<td>Produkt A</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Produkt B</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Produkt C</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-----------</td>
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<td>---</td>
<td>---</td>
<td>---</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Produkt D</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Wie bewerten Sie den Geruch:

<table>
<thead>
<tr>
<th>Produkt A</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Produkt B</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Produkt C</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Produkt D</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Wie bewerten Sie das Mundgefühl während dem Kauen:

<table>
<thead>
<tr>
<th>Produkt A</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Produkt B</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Produkt C</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Produkt D</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Welche(s) der getesteten Produkte vermuten Sie stammt/stammen aus biologischer Landwirtschaft?

- [ ] Produkt A
- [ ] Produkt B
- [ ] Produkt C
- [ ] Produkt D
6.2.1.7 Assessment of hunger and liking of walnuts.

Wie viel Hunger haben Sie?
Beschreiben Sie bitte Ihr Hungergefühl indem Sie auf untenstehender Linie eine Markierung setzen.

![Hunger Scale]

keinen Hunger schwachen Hunger starken Hunger extremen Hunger

Wie sehr mögen Sie Walnüsse im Allgemeinen?

![Liking Scale]

überhaupt nicht teils/teils sehr gerne

6.2.1.8 Additional questions.

Vor wie vielen Stunden haben Sie das letzte Mal etwas gegessen?


Ihre Körpergröße in m:


Ihr Körpergewicht in kg:


6.2.2 Mental Imagery Instructions - Walnuts.

1. Positionieren Sie sich gemütlich auf einem Sessel.

2. Die folgende Vorstellung soll jeweils mindestens 15 Sekunden dauern:
   - Schließen Sie Ihre Augen
   - Stellen Sie sich am Tisch vor Ihnen eine Schüssel voller Walnüsse vor.
   - Stellen Sie sich vor wie Sie eine Nuss heraus nehmen, diese genau ansehen und daran riechen.
   - Stellen Sie sich vor wie Sie die Nuss in den Mund nehmen, sie kauen und dies den Speichelfluss anregt.
   - Stellen Sie sich abschließend vor wie Sie die Nuss herunterschlucken.


4. Wiederholen Sie das ganze 18mal

6.2.3 Mental Imagery Instructions - Coins.

1. Positionieren Sie sich gemütlich auf einem Sessel.

2. Die folgende Vorstellung soll jeweils mindestens 15 Sekunden dauern:
   - Schließen Sie Ihre Augen.
   - Stellen Sie sich vor sie befinden sich in einer Wäscherei und stehen vor einem Waschautomaten.Neben dem Wäscheautomaten steht eine Schüssel voller 50 ¢ Münzen.
   - Sie entnehmen eine 50 ¢ Münze aus der Schüssel und betrachten diese genauer.
   - Danach stellen Sie sich vor, wie Sie die Münze in den Automat einwerfen.
   - Abschließend drücken Sie auf „reset“ um die Münze wieder zu bekommen und legen diese in die Schüssel zurück.


4. Wiederholen Sie das ganze 18mal
6.3 Acknowledgments.

The author would like to acknowledge Sandra Reininger and Theresa Schläger for their assistance during data collection.

Particular thanks are also due to Benjamin Missbach for his valuable feedback, helpful suggestions and support with respect to this thesis.

6.4 CV.

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