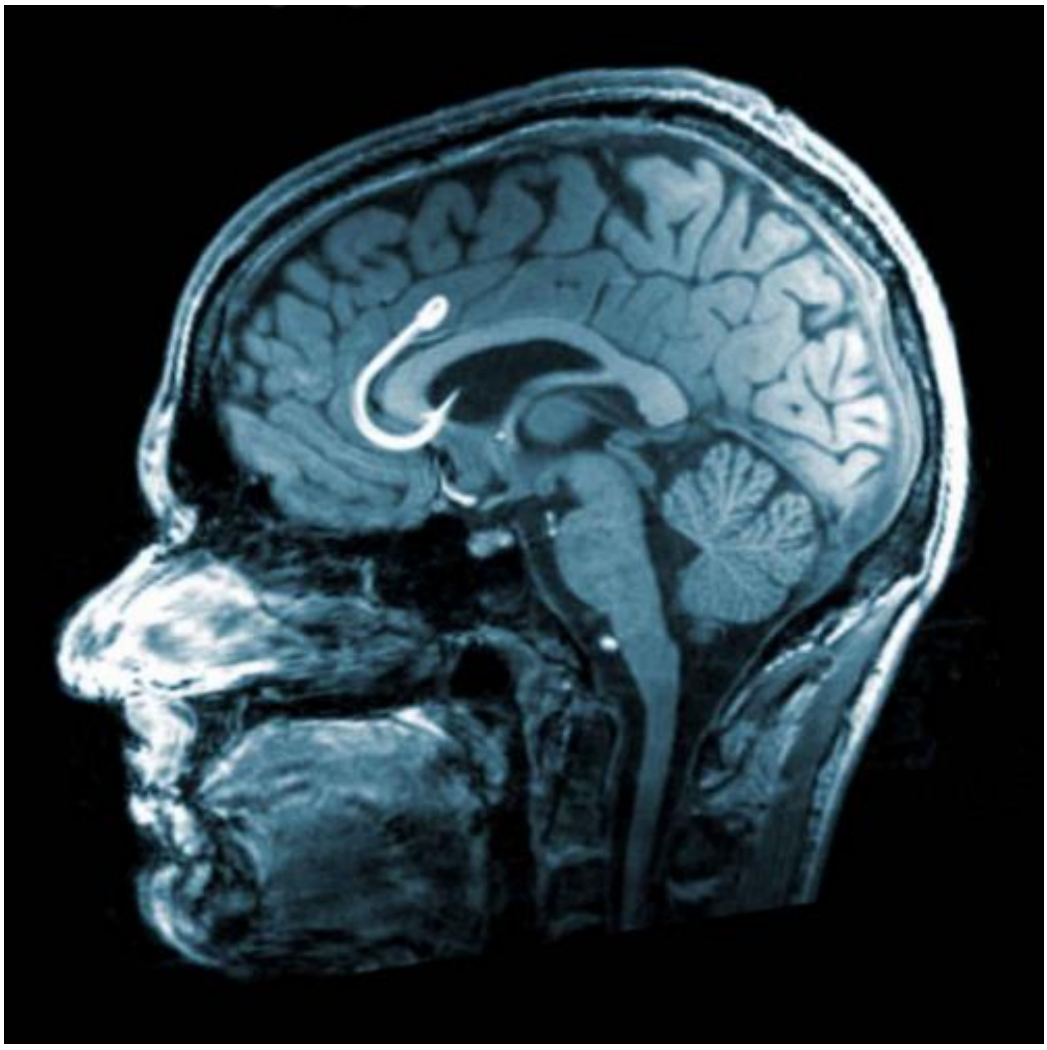
Master's Thesis in Psychology

The neuroscience of addiction: empirical and theoretical perspectives



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Casper Schmidt
Aalborg University

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Abstract

The present Master's thesis investigates, how we are to understand current tendencies in the cognitive neuroscience of addiction in order to create an explanatory model of addiction through the empirical nature of the neural correlates of addiction, as well as through the theoretical content of the mental and physical states of experiencing addiction. The Master's thesis is divided into two matters, which are outlined individually as Part A and Part B of the thesis. Part A of the thesis is a scientific article, which assesses the structural brain correlates of compulsive sexual behavior (CSB), an emerging behavioral addiction. Part B of the thesis seeks to discuss an ontological and a methodological problem that the study leaves unanswered.

In Part A of the thesis, CSB subjects display significant volumetric increases in neural regions such as the ventral striatum and the amygdala, and show volumetric decreases in the left inferior parietal cortex compared to healthy volunteers. Here, it is concluded that CSB subjects demonstrate structural brain changes as a function of their behaviors, which may be indicative of neural correlates for the detrimental effects that CSB subjects report of their behaviors.

In Part B of the thesis, the detrimental effects that CSB subjects report of their behaviors leaves open the potential explanations of subjects' addictions, apart from having measured their neural correlates of their behaviors, and which highlights the purpose of creating an explanatory model of addiction, which is able to problematize the relationship between the mental and the physical. This leads to a theoretical account of two arising problems, which highlight problematic aspects of neuroscientific research on addiction.

The ontological problem, which is related to the type of explanation that can be used to understand the relation between the mental and the physical, leads to a discussion on the metaphysics of the mind, along with a discussion on the situated view on the mind. This section concludes with taking an anti-reductionist position towards the ontological problem. The methodological problem, which is related to how it is methodologically possible to measure the content of the mental and the physical, leads to an integration of the addiction model.

The thesis concludes that the addiction model is able to provide a foundation for explaning addiction. As such, the addiction model rests on and points towards how both mental and physical properties are necessary in providing explanatory accounts of addiction.

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Preface

> I never used to like pornography, not really. Yes, in my teens in the Seventies I used to have the odd copy of Playboy under my pillow. But on the whole I didn't really go for skin mags or blue movies. I found them tedious, repetitive, absurd, and very embarrassing to buy. (Doidge, 2007)

Martin [*edited name*] was repelled by the pornography scene. But in 2001, when he went online, he became curious about the pornography everyone said was taking over the Internet. What he found was an endless variety of different kinds of sexually explicit material – a few of which attracted his attention and liking intensely. These were the very pictures that took him back the following day, and to which he quickly habituated. After a while, he found himself hungrily checking out this material as soon as the possibility arose. One day, Martin came across a website that featured spanking images, which to his surprise got him highly aroused.

> This was the moment that the real addiction set in. My interest in spanking got me speculating: What other kinks was I harboring? What other secret and rewarding corners lurked in my sexuality that I would now be able to investigate in the privacy of my home? Plenty, as it turned out. [...] The Net had, in other words, revealed to me that I had an unquantifiable variety of sexual fantasies and quirks and that the process of satisfying these desires online only led to more interest. (ibid.)

Martin was caught. Though trying to control himself, he was spending five hours a day on his laptop, secretly surfing and sleeping only few hours at night. Very clearly, something about Martin's sexuality had surfaced in the form of addiction. But should this be attributed to the facilitative role of the Internet or to his innate sexuality? And why are these different questions raised, occurring at different levels of explanation for his addiction: with both societal and neuroscientific accounts of addiction?

Clear tendencies are seen in that society and history can alter out preferences and tastes (Doidge, 2007). Acquired tastes are by definition learned, while tastes are by definition innate. For example, in East Africa, certain Masai tribes use urine from cows to lotion their hair – a direct consequence of the importance of the cow in their culture (ibid.). Like this rather extreme example, many tastes we perceive to be natural are acquired through learning. Hence, we sometimes become unable to distinguish learned from innate behavior because of the fact that the plastic potential of our brains is conditional for these acquired tastes. Then, our learning becomes intertwined with our nature and biology, once again creating and forming what will become part of our new nature.

The revolving question for the present Master's thesis is whether the social impact of the Internet simply reveals these preferences on the premise that they are pre-existing, or whether it is also facilitating in the creation of these. This question is raised on the basis of having assessed the neural correlates of compulsive sexual behavior (CSB). This further relates to a more fundamental ontological problem of mental and physical properties of addiction, and the relationship between different explanations of the causes and effects of human behavior.

To return to the case of Martin, his experience is similar to a lot of patients who have seen therapists for their behavioral addictions, be it CSB, pathological gambling (PG), binge eating (BE), binge drinking (BD), or obsessive-compulsive disorder (OCD). The former, however, is of particular interest for the thesis in terms of the societal shift taking place, which can be attributed to a multifaceted array of factors. Furthermore, the Master's thesis examines a methodological problem, and presents an addiction model, which seeks to delineate the relationship between mental and physical properties of addiction, and thus to make a scientific contribution to the neuroscience of addiction.

1. Introduction

1.1 The matter of the thesis

The present Master's thesis will investigate the structural brain correlates of a behavioral addiction and its connection to certain theoretical perspectives on psychology and neuroscience. Here, two matters are sought investigated, the first of which is an empirical investigation of the structural brain correlates of *compulsive sexual behavior* (CSB), and the second of which is a theoretical examination of two problems; an ontological and a methodological one, which the empirical study leaves unaddressed, and which relates to the metaphysics of the mind, causality and methodology, and on behalf of which a novel model of addiction will be created to conclude the thesis' findings.

The first matter of the thesis will consist of a scientific article that will contribute with new neuroscientific evidence. An introduction will be place the study in its neuroscientific context. The methods section will include a full literature review of all reported studies on structural brain correlates of four different behavioral addictions. Furthermore, the methods section will cover information on the data description in the form of participants, data acquisition, data processing and data analysis. The results section will connect the main and secondary findings with the introduction section. The discussion will sum up the findings and place them within the literature already in existence. Here, the results will be discussed on both the premise of converging and divergent evidence. Conjectures of the explanatory value of the findings are discussed along with the study's limitations. Finally, conclusions and recommendations for future research will be stated.

The second matter of the thesis consists of theoretical perspectives on behalf of the scientific study, and discusses two theoretical problems that the scientific study leaves unanswered; an ontological and a methodological one. A historical outline will be provided for the grounding of the later discussion on why there seem to exist both a societal and a neuroscientific explanation of the emergence of CSB. Subsequently, the ontological problem is treated, which is related to the type of explanation that can be used to understand the relation between the mental and the physical, and which leads to a discussion on the metaphysics of the mind. The next chapter provides an extended discussion on the situated emergence of the mind and causality related to the ontological problem. The next chapter addresses the methodological problem related to, how it is methodologically possible to measure the content of the mental and the physical, through a discussion on specific aspects of mental and physical accounts of addiction on the basis of the conclusions from previous chapters. The last chapter concludes the treatments of the ontological and methodological problem, and presents a novel explanatory model of addiction on behalf of the conclusions of the thesis.

1.2 Problem statement

How are we to understand current tendencies in the cognitive neuroscience of addiction in order to create an explanatory model of addiction through:

1) The empirical nature of the neural correlates of addiction?
2) The theoretical content of the mental and physical state of being addicted?

1.3 Definitions of concepts

The Master's thesis is subject to a discussion on the philosophy of mind, a line of philosophy that draws on many different concepts and philosophical positions. Here is provided a short list of definitions of the concepts frequently used. These definitions are all from '*The Cambridge Handbook of Philosophy*' in order to keep a stringency for the definitions of the used concepts, although few additional sources are provided if relevant in context of the concepts defined.

Supervenience is a dependence relation between properties or facts of one type, and properties or facts of another type (Audi, 1999, p. 891). According to the definition, supervenience is a relation between properties that can be stated as follows: Properties of type *A* are supervenient on properties of type *B* if and only if two objects cannot differ with respect to their *A*-properties without also differing with respect to their *B*-properties (ibid.). This was first heralded by Davidson in articulating a position on the relation between physical and mental properties that abandons the reducibility of mental properties to physical ones. This framework will be elaborated later, and hence, Davidson's definition will stand by itself here:

> Although the position I describe denies there are psychophysical laws, it is consistent with the view that mental characteristics are in some sense dependent, or supervenient, on physical characteristics. Such supervenience might be taken to mean that there cannot be two events alike in all physical respects but differing in some mental respects, or that an object cannot alter in some mental respects without altering in some physical respects. Dependence or supervenience of this kind does not entail reducibility through law or definition. (Davidson, 1970 cf. Audi, 1999, p. 891)

Mental causation can be termed as the concept of voluntary action, or doing, which involves the idea that an agent (intentionally) causes a change in some object or other (Audi, 1999, p. 125). A proportionate antonym would be that of perception, which involves the idea that the object perceived causes in the perceiver an appropriate perceptual experience (ibid.). Another definition of mental causation is the way that the mental exercises causal influences in the physical world (Kim, 2000, p. 29). This additional definition will be a key concept in a later discussion.

Emergentism is the idea that a given whole holds property that together, its parts lack (Audi, 1999, p. 391). Similarly, the properties that the whole hold, cannot be defined by properties of its parts (ibid.). Another frame of reference for emergentism is that it does not deny that mental properties can be non-physical in their nature and as possessing intrinsic causal powers (Kim, 2000, p. 12).

Reductionism is defined as a general pattern of reduction that involves 'identity statements' or 'bridge laws' with explicit definitions for all terms in the reduced entity (Audi, 1999, p. 778f). Here, in order to understand bridge laws in the present interest, a further definition will be given: "*bridge laws* […] *provide the essential reductive links between the vocabulary of the theory targeted for reduction and that of the base theory, and thereby enable the derivation of the target theory from its reducer*" (Kim, 2000, p. 90). This relates to the thesis' focus on, whether the mental is amenable to reductive explanation or if it resists this.

Qualia are those properties of mental states or events, in particular of perceptual states, which determine 'what it is like' to have them, according to Audi (Audi, 1999, p. 762). Qualia are also thought of as non-intentional and non-representational features of the states that have them. In case of a person's experience of green being 'qualitatively' just like another person's experience of red, the visual experiences the two have when viewing a tomato would be alike in their intentional features, in that both would be *of* a red and round surface, but would have different qualia (ibid.).

Lastly, when 'psychological' and 'neural' properties are used in combination, these are to be set aside with an adaption of 'mental' and 'physical' properties. This takes place in later chapters.

1.4 Rationale behind thesis topic

The thesis revolves around CSB, a fairly new and emerging behavioral addiction that more and more people are seeking therapists for. The reasons for this particular interest in CSB lie the societal shift taking place on the increasing availability of sexually explicit material, which is attributed to a large array of factors such as media, technology, and individualism. During the period of 2001-2004, an estimate of 18 million people visited adult websites monthly; a statistic that more than quadrupled during the period of 2005-2008 to 75 million (Ropelato, 2007, p. 2). Newer valid statistics do not yet exist but with the exponential growth, almost certainly the number has increased. By 2006 it was estimated that the average age of the first Internet exposure to sexually explicit material was 11 years of age in the USA (ibid.). Undeniably, a societal shift is taking place.

These statistics are particularly interesting from a neuroscientific perspective in considering some of the conditioning factors for developing addiction, where especially age plays a critical role in the plastic potential of the brain. Furthermore, the Master's thesis' discussion on, why there exist both societal and neuroscientific explanations of a phenomena such as addiction, stems from a fascination of, why it is intuitive to attribute separate causes for the emergence of certain phenomena that seem associated with a particular environment.

1.5 Structure of the thesis

The thesis is divided into two matters, each of which is divided into chapters beginning subsequent to this introductory chapter one. The first matter of the thesis is presented in chapter two, which assesses the structural brain correlates of CSB and includes all sections of the scientific study.
The second matter of the thesis is comprised in chapter three to six, which takes up ontological and methodological problems left unanswered by the scientific study, and begins with an examination of the historical antecedents of situated cognition and cognitive neuroscience. Chapter four and five comprise a discussion of the ontological problem, in which chapter four takes on a discussion on the metaphysics of the mind using a key frame from philosopher of mind, Jaegwon Kim. Chapter five comprises a discussion on the situated nature of the mind as an opposition to the arguments from chapter four. Chapter six presents the methodological problem, qualitative reports from addicts and relevant neuroscientific evidence as equivalents of mental and physical measures of addiction. Chapter seven presents and integrates the addiction model, and concludes the findings of the thesis.

1.6 Thesis limitations

The present thesis will primarily treat the specific addiction of CSB, a behavioral addiction which holds specific characteristics. There are limitations to the depths of chapter four and five, especially, where single prominent positions have been chosen for their recognition and potential for fruitful discussion due to the limits of the thesis. Many other perspectives on and philosophers of mind from reductionism and emergentism could have been included. In this regard, the reader should be attentive to the limited frame for the thesis, and that there have been made necessary opt-outs. There will be a discussion on *aspects* of ontological and methodological problems, and perspectives and examples have been carefully chosen with regard to answering the problem statement. Thus, other relevant aspects of these theories are sometimes left out of discussion, due to the limits of the thesis.

2. Thesis Part A – Compulsive sexual behavior predicts volumetric brain changes in regions related to addiction

Abstract *Background:* The Internet provides an unending source of novel and rewarding sexually explicit material. The present study examines the structural brain correlates as a consequence of excessive use, defined as CSB, hypothesizing a greater volumetric increase in brain regions related to addiction relative to controls.
Methods: Twenty-three CSB males and 69 age-matched male healthy volunteers were scanned using magnetic resonance imaging. Scans were analyzed and assessed using voxel-based morphometry.
Results: CSB subjects displayed significant volumetric increases in regions such as the ventral striatum and the amygdala and showed volumetric decreases in the left inferior parietal cortex compared to healthy volunteers.
Conclusions: CSB subjects demonstrate structural brain changes as a function of their behaviors. This may be indicative of neural correlates for the detrimental effects that CSB subjects report of their behaviors.

Introduction

Over the past decades there has been an increasing interest in syndromes involving excessive sexual desires and urges (Miner et al., 2009). This syndrome, widely termed as compulsive sexual behavior (CSB; Quadland, 1985), includes diagnostic criteria requiring the presence of recurrent and intense sexually arousing fantasies, sexual urges, or sexual behaviors over a period of at least six months that cause distress or impairment to the individual (Coleman et al., 2000).

Conceptually, CSB has been defined as either an impulse control disorder or a non-substance behavioral addiction and has been proposed to be included in the DSM-V (Kafka, 2010; Winters et al., 2010; Screiber et al., 2012; Kor et al., 2013). So far though, no behavioral addictions such as CSB, excessive Internet use, or video-gaming have been included as psychiatric diagnoses, this in part being attributed to limited data in the different lines of research (Flisher, 2010; Petry & O'Brien, 2013).

However, there have been noticed structural brain changes in these behavioral addictions in both cortical and subcortical brain regions. Throughout the range of studies in the literature where either voxel-based morphometry (VBM) or Cortical Thickness Analysis (CTh) has been performed to assess structural brain changes in behavioral addictions, converging evidence can be linked across different behavioral addictions.

In Internet Addiction (IA), a volumetric decrease in gray matter (GM) density in the left anterior cingulate cortex (ACC), the left posterior cingulate cortex (PCC), the left insula and the left lingual gyrus has been observed (Zhou et al., 2011). In another IA study, there was found a volumetric decrease in the rostral ACC in addition to the orbitofrontal cortex (OFC), the supplementary motor area (SMA), the dorsolateral prefrontal cortex (DLPFC), and the cerebellum (Yuan et al., 2011). In a cortical thickness study in IA, a decrease in cortical thickness was found in the right lateral OFC, convergent with the findings of Yuan et al. (Hong et al., 2013). Similar brain regions have shown to be altered across addictions such as IA and Internet gaming addiction (IGA). In IGA studies, volumetric and density decreases have been found in the amygdala, the ACC, the insula, the inferior frontal gyrus (IFG) and the precuneus (Lin et al., 2015). Convergent with these findings, in online game addiction (OGA) studies, decreases in GM volume have been found in the right OFC, the bilateral insula, and the right SMA (Weng, et al., 2013).

Cortical thickness studies in IGA have found increased cortical thickness in the precuneus (Yuan et al., 2013), divergent with the findings of volumetric decreases in the precuneus by Lin (Lin et al., 2015). However, this study also found similar evidence with the previously listed implicated regions as decreases in cortical thickness were found in the OFC, the insula, and in the lingual gyrus (ibid.). Volumetric alterations have also been found with studies in Internet Gaming Disorder (IGD). Here, there have been observed volumetric decreases in the ACC, the superior parietal cortex (SPC), the precuneus, the SMA, the left DLPFC, the left insula and the cerebellum (Wang et al., 2015) as well as a recent study found a significant volumetric increase in the right VS, and that right VS volume was positively correlated with Internet addiction test results (Cai et al., 2015).
Finally in obesity, convergent results have been found in the form of volumetric decreases in the DLPFC (Brooks et al., 2013), as well as two independent CTh studies in obesity that both found decreased cortical thickness in the OFC (Marquéz-Iturria et al., 2013; Ross et al., 2015).

Other behavioral addictions such as pathological gambling (PG) have been examined, and there has been found sufficient evidence for classification of PG in the main section of the DSM-V as a behavioral addiction (Association AP, 2013), this in spite of structural brain changes not having been unanimously distinguished from the brains of healthy controls. In one of the two PG studies where VBM has been performed, no difference in GM or white matter (WM) was found between pathological gamblers and controls (Joutsa et al., 2011). However, in another PG study where VBM has been performed, there was found an increase in GM volume in the bilateral ventral striatum

(VS) and in the right prefrontal cortex (PFC) (Koehler et al., 2013). However, in gambling disorder (GD) where CTh was performed, there was found reduced cortical thickness in regions such as the superior and middle frontal cortices, the right medial OFC, the left inferior parietal cortex (IPC) and the right post-central cortex (Grant et al., 2015). In problem gambling, an addiction with less severe diagnostic criteria, VBM was performed and here, there was found no differences in either GM or WM volume (van Holst et al., 2012).

Given the similarities between the short term outcomes of substance abuse and behaviors that elicit impaired control over pleasure or rewards such as gambling or CSB, further investigations into the behavioral and neural properties of such behaviors need to be addressed. This is necessary in order to further determine, whether CSB can be legitimized as an impulse control disorder or a non-substance behavioral addiction as currently, there is a lack of evidence supporting a clear distinction between the two. With this call for further assessment, future studies on CSB should aim to pinpoint, which demarcations for classification are fit for diagnostic purposes including the underlying neural and behavioral correlates for these. The findings are placed in the context of previous studies on both neural activation and structural properties of the brain in CSB subjects as well as in other behavioral addictions and how these results relate to and dissociate from previous studies.

Prior studies and a recent meta-analysis of substance abuse showed larger activity relative to controls across types of addiction such as alcohol, nicotine, and cocaine, and CSB in the VS, dorsal anterior cingulate cortex (DACC), and amygdala (Schultz et al., 1992; Kühn & Gallilat, 2011; Voon et al., 2014). Another recent study performed VBM on healthy volunteers to look at the structural effects in the brains of non-addicted pornography consumers. Here, pornography consumption negatively correlated with GM volume in the right caudate (Kühn & Gallilat, 2014). What has yet to be assessed in this line of research is, whether CSB subjects exhibit volumetrically changed structural aspects of the brain.

In this study, we examine the neural correlates of CSB. This has been done by observing volumetric brain changes associated with CSB and by investigating and analyzing the structural properties of CSB subjects' brains compared with healthy controls in order to further establish these volumetric brain alterations. The novel properties of the present study lie in comparing structural brain scans on groups both with and without CSB, in order to further assess which regions may be different in size

and hence possibly function. We compared individuals with and without CSB and hypothesized volumetric brain differences in several regions. This hypothesis was made for the VS, which is assumed to be heavily involved in habit formation when drug use progresses to compulsive behaviors (Gerdeman et al., 2003), and has shown to be involved in cue-reactivity processing of various drugs of abuse (Kühn & Gallilat, 2011). The hypothesis was also made for the amygdala, the SMA, and the DACC as in line with previous studies on behavioral addictions, these regions could likely be involved in the processing of and responding to sexually explicit stimuli. Given the potential involvement of mesolimbocortical circuitry, volume in the substantia nigra (SN) was also assessed on an exploratory level because of its involvement in dopaminergic transmission and in brain activation to sexual stimuli (Sescousse et al., 2013; Voon et al., 2014).

Methods

Literature review and search criteria

A review of the literature was performed on previous structural brain analyses assessed on behavioral addictions using either VBM or CTh. For this review, we used the following search words on PubMed (http://www.ncbi.nlm.nih.gov/pubmed): "[('voxel based morphometry' or 'cortical thickness') and]", followed by either "[pathological gambling]", "[Internet addiction]", "[Internet disorder]", "[video gaming addiction]", "[gaming addiction]", or "[obesity]". In total, 18 studies were found within behavioral addictions related to gambling, Internet use, video gaming, or obesity that assessed either VBM or CTh. The review of the literature is presented in *Table 1*.

Table 1. Literature review of studies on behavioral addictions where either VBM or CTh has been assessed.

Title	Behavioral Addiction	Subjects (PG/HV)	Measure	Regions implicated	Statistical analyses	Comments
Reduced cortical thickness in gambling disorder - a morphometric MRI study (Grant et al., 2015)	Gambling Disorder	16 / 17	Cortical thickness	Decreased cortical thickness in right superior frontal, right rostral middle frontal, right rostral middle frontal, right medial orbitofrontal, left inferior parietal, right post-central gyrus, right supramarginal, and right superior frontal	Whole brain, $P < 0.05$ uncorrected, between groups	
Extensive abnormality of brain white matter integrity in pathological gambling (Joutsa, 2011)	Pathological Gambling	12 / 12	Voxel-based morphometry	No volumetric differences in gray matter or white matter between pathological gamblers and controls	Whole brain, $P < .001$ uncorrected, between groups	
Higher volume of ventral striatum and right prefrontal cortex in pathological gambling (Koehler et al., 2013)	Pathological Gambling	20 / 21	Voxel-based morphometry	Increased gray matter volume in bilateral ventral striatum and right prefrontal cortex	Whole brain, $P < 0.001$ uncorrected, between groups	
A voxel-based morphometry study comparing problem gamblers, alcohol abusers, and healthy controls (van Holst, 2012)	Problem Gambling	40 / 54	Voxel-based morphometry	No volumetric differences in gray matter or white matter between pathological gamblers and controls	Whole brain, $P < 0.05$ FDR-corrected, between groups	Problem gambling; weaker diagnostic criteria
Reduced orbitofrontal cortical thickness in male adolescents with internet addiction (Hong et al., 2013)	Internet Addiction	15 / 15	Cortical thickness	Decreased cortical thickness in right lateral orbitofrontal cortex	Region of Interest (ROI), $P < 0.05$, between groups	No report of ROI correction
Microstructure abnormalities in adolescents with internet addiction disorder (Yuan et al., 2011)	Internet Addiction	18/18	Voxel-based morphometry	Decreased gray matter volume in dorsolateral prefrontal cortex, supplementary motor area, orbitofrontal cortex, cerebellum and rostral anterior cingulate cortex	Whole brain, $P < 0.05$, between groups	No report of whole brain correction, adolescent addiction
Gray matter abnormalities in Internet addiction: A voxel-based morphometry study (Zhou, 2011)	Internet Addiction	15/18	Voxel-based morphometry	Decreased gray matter density in left anterior cingulate cortex, left posterior cingulate cortex, left insula, and left lingual gyrus	Whole brain, $P < 0.05$ FDR-corrected, between groups	
Abnormal gray matter and white matter volume in 'Internet gaming addicts' (Lin et al., 2015)	Internet Gaming Addiction	35 / 36	Voxel-based morphometry	Decreased gray matter density in the inferior frontal gyrus, left cingulate gyrus, insula, right precuneus, and right hippocampus Decreased white matter density in the inferior frontal gyrus, insula, amygdala, and anterior cingulate cortex.	Whole brain, $P < 0.05$ FDR-corrected, between groups	
Assessment of in vivo microstructure alterations in gray matter using DKI in Internet gaming addiction (Sun et al., 2014)	Internet Gaming Addiction	18 / 21	Voxel-based morphometry	Increased gray matter volume in the right inferior and middle temporal gyri, and right parahippocampal gyrus Decreased gray matter volume in the left precentral gyrus	Whole brain, $P < 0.001$ uncorrected, between groups	
The alteration of gray matter volume and cognitive control in adolescents with internet gaming disorder (Wang et al., 2015)	Internet Gaming Disorder	28 / 28	Voxel-based morphometry	Decreased gray matter volume in anterior cingulate cortex, precuneus, supplementary motor area, superior parietal cortex, left dorsolateral prefrontal cortex, left insula, and cerebellum		No clear reporting on VBM statistics

Gray matter and white matter abnormalities in online game addiction (Weng et al., 2013)	Online Game Addiction	17 / 17	Voxel-based morphometry	Decreased gray matter volume in right orbitofrontal cortex, bilateral insula, and right supplementary motor area	ROI, $P < 0.05$, between groups	No report of ROI correction, (screened and fulfilled criteria for Internet Addiction)
Cortical Thickness Abnormalities in Late Adolescence with Online Gaming Addiction (Yuan et al., 2013)	Online Game Addiction	18 / 18	Cortical thickness	Increased cortical thickness in left precentral cortex, precuneus, middle frontal cortex, inferior temporal and middle temporal cortices Decreased cortical thickness in left lateral orbitofrontal cortex, insula, lingual gyrus, right postcentral gyrus, entorhinal cortex and inferior parietal cortex	Whole brain, $P < 0.05$ FDR-corrected, between groups	Late adolescent addiction
Brain abnormalities in human obesity - a voxel-based morphometric study (Pannacciulli et al., 2006)	Obesity	24 / 36	Voxel-based morphometry	Decreased gray matter density in post-central gyrus, frontal operculum, putamen, and middle frontal gyrus	Whole brain, $P < 0.01$ FDR-corrected, between groups	
Cortical thickness of the cognitive control network in obesity and successful weight loss maintenance - A preliminary MRI study (Hassenstab et al., 2012)	Obesity	17 / 17	Cortical thickness	Decreased cortical thickness in the anterior cingulate and posterior parietal cortices	ROI, $P < 0.05$, between groups	No report of ROI correction
Brain structural correlates of reward sensitivity and impulsivity in adolescents with normal and excess weight. (Moreno-Lopez et al., 2012)	Obesity	36 / 16	Voxel-based morphometry	Increased gray matter volume in right hippocampus	Whole brain, $P < 0.001$ uncorrected, between groups	Adolescent obesity
Late-life obesity is associated with smaller global and regional gray matter volumes – a voxel-based morphometric study (Brooks et al., 2012)	Obesity	59/97	Voxel-based morphometry	Decreased gray matter volume in dorsolateral prefrontal cortex	Whole brain, $P < 0.05$ FWE-corrected, between groups	Late adulthood obesity
Frontal cortical thinning and subcortical volume reductions in early adulthood obesity (Marquéz-Iturria, et al. 2013)	Obesity	19 / 18	Cortical thickness	Decreased cortical thickness left superior frontal and right medial orbitofrontal cortex	Whole brain, $P < 0.05$ Monte Carlo corrected, between groups	Early adulthood obesity
Obesity, fitness, and brain integrity in adolescence (Ross et al., 2015)	Obesity	79 / 51	Cortical thickness	Decreased cortical thickness in orbitofrontal cortex	Whole brain, $P < 0.05$, between groups	No report of whole brain correction

Table 2. Demographic and behavioral data for CSB subjects and healthy volunteers.

Group	Age	BDI	UPPS-P
CSB subjects (N = 23)	26.9 (6.2)	13.81 (11.07)	149.64 (18.39)
Healthy volunteers (N = 69)	25.9 (6.5)	5.77 (7.02)	124.93 (19.90)
T-value (p-value)	0.89 ($P = 0.380$)	3.19 ($P = 0.003$)	4.38 ($P < 0.001$)

Reports on standard deviations and p-values for two-sampled t-tests are in brackets.

Participants

CSB subjects were recruited via referrals from therapists and from a conference in sexual addiction, where both went through a licensed psychiatrist. Diagnostic screening was completed using the Internet Sex Screening Test (ISST) (Delmonico & Miller, 2003) and an extensive investigator designed questionnaire surrounding details on the compulsive behaviors, such as age of onset, frequency, duration, attempts to control use, abstinence, patterns of use, treatment, and negative life consequences. Further screening was done continually via telephonic communication. Finally, all CSB subjects underwent a face to face interview with a psychiatrist to confirm that they met diagnostic criteria for CSB (Kafka, 2010; Reid et al., 2012; Carnes, Griffin & Delmonico, 2001). All of the recruited CSB subjects also met the proposed diagnostic criteria for Hypersexual Disorder and sexual addiction (ibid.). All of both the CSB subjects and the healthy volunteers were male and heterosexual. The CSB subjects and the healthy volunteers were matched in age (~5 years) across groups in a 1 to 3 ratio. 23 CSB subjects and 69 healthy volunteers participated in the study. Participants were between 18 and 45 years of age. Exclusionary criteria included being less than 18 years of age, having a history of substance-use disorders, being a current regular user of illicit substances, or having a serious psychiatric disorder, including current moderate-severe major depression (Beck Depression Inventory .20), obsessive-compulsive disorder, or history of bipolar disorder or schizophrenia (Mini International Neuropsychiatric Inventory) (Sheehan et al., 1998). Other compulsive or behavioral addictions also functioned as exclusion criteria.

Subjects were assessed by a licensed psychiatrist regarding problematic use of online video-gaming or social media, pathological gambling or compulsive shopping, childhood or adult attention deficit hyperactivity disorder, and binge-eating disorder diagnosis. Subjects were also screened for compatibility with the MRI environment. Not being suitable for the MRI environment, or having a major neurological illness or head injury also functioned as exclusion criteria in the study. Of questionnaires, subjects completed the UPPS-P Impulsive Behavior Scale (Whiteside & Lynam, 2001) to assess impulsivity, Beck Depression Inventory (Beck et al., 1961) and State Trait Anxiety Inventory (Spielberger et al., 1983) to assess depression and anxiety, respectively, Obsessive Compulsive Inventory R to assess obsessive-compulsive features and the Alcohol-Use Disorders Identification Test (AUDIT) (Saunders et al., 1993). General Internet use was assessed using the Young's Internet Addiction Test (YIAT) (Young, 1998) and the Compulsive Internet Use Scale (CIUS) (Meerkerk et al., 2009). The National Adult Reading Test (Nelson, 1982) was used to

obtain an index of IQ. A modified version of the Arizona Sexual Experiences Scale (ASES) (McGahuey et al., 2000) was used with one version relevant to intimate relationships and another version relevant to online sexually explicit material. Written informed consent was obtained, and the study was approved by the University of Cambridge Research Ethics Committee. Subjects were paid for their participation in the study. As behavioral statistics, subjects' questionnaire scores were compared using two sample t-tests.

Neuroimaging

Data Acquisition

Structural images were collected including full magnetization prepared gradient-echo (MPRAGE) and resting state connectivity of the participants in 30 minute scan slots. Images were collected using a Siemens Tim Trio 3T-scanner with a 32-channel head coil using a T1 weighted MPRAGE sequence (176 sagittal slices, 9 minute scans; repetition time (TR) = 2500 milliseconds; echo time (TE) = 4.77 milliseconds; inversion time = 1100 milliseconds; acquisition matrix = 256 * 256 * 176; flip angle = 7°; voxel size 1 * 1 * 1 mm). Scanning took place at The Wolfson Brain Imaging Centre at the University of Cambridge. Participants were instructed to stay awake and at the same time to relax during the scan.

Data Processing

Structural data was processed with VBM (VBM; http://dbm.neuro.unijena.de/vbm.html) and Statistical Parametric Mapping (SPM; http://www.fil.ion.ucl.ac.uk/spm) (Wellcome Trust Centre for Neuroimaging, London, UK). Pre-processing of the images consisted of slice-time correction, spatial realignment, co-registration with the subjects' T1-weighted structural images, normalization to MNI space, and spatial smoothing. Using VBM in SPM incorporates bias correction, tissue classification, and affine-registration. The GM and WM segmentations were used to build an iterated brain template. Warped GM and WM segments were created, and modulation with Jacobian determinants was applied to measure the volume of a particular tissue within a voxel, leading to a measurement of GM volume. Images were smoothed spatially with a full width at half maximum kernel of 8 mm. Whole-brain calculation of GM, WM and cerebrospinal fluid (CSF) volumes were computed for all subjects, creating a measure each participant's total intracranial volume (TICV). Ages and the TICVs of subjects' brains were entered as covariates of no interest, and BDI and UPPS-P scores were correlated with volumetric properties and groups' differences as covariates.

The resulting maps were set at a threshold of $P = 0.001$, and statistical extent threshold was used to correct for multiple comparisons (Hayasaka & Nichols, 2004). The first three volumes of each session were discarded to allow for T1-equilibration effects.

Statistical Analyses

General linear models (GLMs) were used for comparing the GM, WM and CSF concentrations from the CSB subjects and healthy volunteer groups. Models controlling for age, BDI and UPPS-P scores were also applied. All models used were corrected for participants' TICVs as covariates using proportional scaling and an explicit mask in SPM8. To enforce an *a priori* threshold of $P = 0.05$ corrected for multiple comparisons, the whole brain voxel-wise group comparisons were performed with a cluster extent threshold correction which was calculated at 19 voxels at a threshold of $P = 0.001$, whole brain FWE-uncorrected (Slotnick et al., 2003). By doing this, a correction for multiple comparisons at $P = 0.05$ took place, assuming an individual voxel Type 1 error of $P = 0.01$.

Volumetric differences above whole-brain FWE-uncorrected, $P = 0.001$ were considered significant between groups with and without age interactions, focusing on *a priori* hypothesized regions of interest. These, including VS, amygdala, SMA, and DACC were conducted if the contrast of condition (e.g. CSB > HV; HV > CSB) identified regions significantly different at the whole-brain level (FWE-uncorrected, $P = 0.001$). The VS, amygdala, SMA, and DACC were hypothesized as regions involved as well. For these regions with strong *a priori* hypotheses, we used the ROIs with a threshold for significance set at $P = 0.05$ (FWE-uncorrected). As mentioned in the introduction, the substantia nigra (SN) was assessed on an exploratory level which appeared descriptively on the whole brain map, and this region was used as an ROI as well. Taking into account the *a priori* hypotheses of certain regions might being affected in CSB subjects, we had hypothesis of observed differences in VS, amygdala, SMA and DACC. Here, we had the privilege of comparing groups using small volume corrections (SVCs) to the GLM, targeting these hypothesized regions. The anatomical localization for these regions were obtained from the Montreal Neurological Institute (MNI) coordinates using MRIcron (Rorden et al., 2007), as well as using .aal templates either created manually or in WFU PickAtlas templates in SPM8 Toolbox (Maldjian et al., 2003). An FWE-uncorrected threshold of $P = 0.001$ was used within the SVCs to determine the significance of the results from these tests. Additional GLMs with BDI and UPPS-P scores as covariates were

tested on whole brain level. Correlations with BDI and UPPS-P scores were performed on a whole brain, FWE-uncorrected threshold of $P = 0.001$ to determine the significance of the results from these tests. All demographical and behavioral data as well as the questionnaires with BDI and UPPS-P scores were compared between groups with two-tailed t-tests without assuming equal variance. All descriptive statistical analyses including questionnaires and demographic data were performed using R version (3.2.0) (R Core Team 2014) with packages ggplot2 (v1.0.1).

Results

Characteristics

Twenty-three heterosexual men with CSB (age 26.91; SD 6.22 years) and 69 age-matched (age 25.57; SD 6.55 years) heterosexual healthy volunteers without CSB were studied (see *Table 2*). 74 subjects (19 CSB; 55 HV) completed behavioral questionnaires, and BDI and UPPS-P scores were compared between groups. Using a two sampled t-test between CSB subjects and healthy volunteers, CSB showed both higher BDI ($P = 0.003$) and UPPS-P ($P < 0.001$) scores when compared to healthy volunteers.

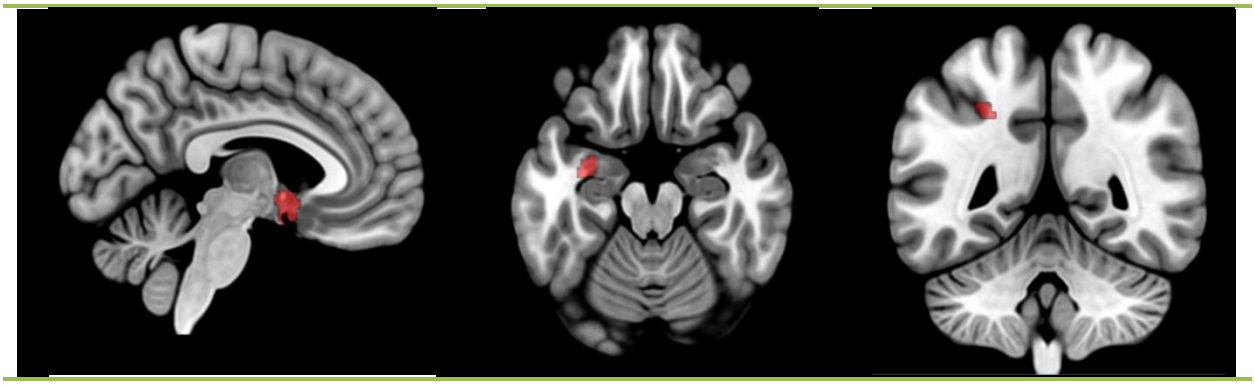

Figure 1. Main significant regions and corresponding bar plots. Sagittal: VS. Axial: left amygdala. Coronal: left IPC

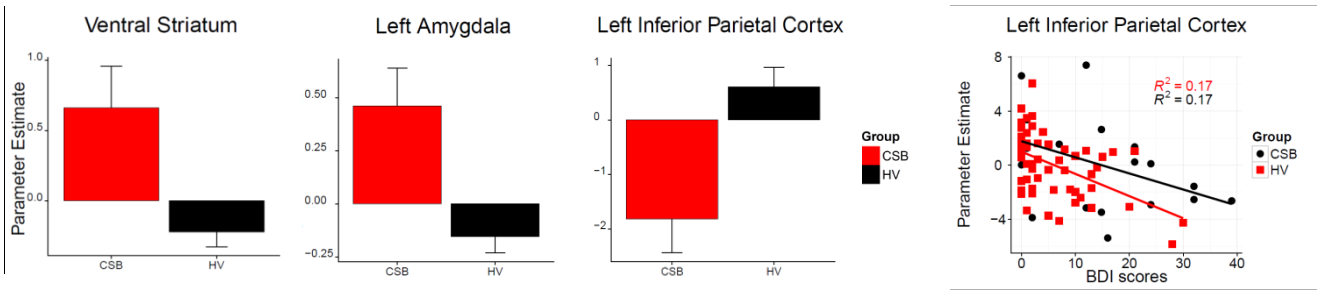

Figure 2. Correlation between parameter estimates and BDI scores in CSB and HV subjects (right).

Imaging analyses

No between-group main-effect brain activation differences survived whole-brain FWE-correction at $P = 0.05$. Therefore, an uncorrected threshold of $P = 0.001$ was used, and whole brain differences appeared in several brain regions. At this threshold, cluster extent threshold analysis revealed that CSB subjects have increased volume in the VS (whole brain, $P = 0.001$, FWE-uncorrected, 80 ^{k}E, Z = 3.44, MNI -3, 5, -8) and the left amygdala (whole brain, $P = 0.001$, FWE-uncorrected, 65 ^{k}E, Z = 3.59, MNI -32, -4, -17) compared to controls. On the reverse contrast cluster extent threshold analysis revealed that CSB subjects have decreased volume in the left IPC (whole brain, $P = 0.001$, FWE-uncorrected, 30 ^{k}E, Z = 3.28, MNI -28, -49, 43).

Furthermore, CSB subjects, when compared with healthy controls, showed a significant volumetric increase in the left angular gyrus (whole brain, $P = 0.001$, FWE-uncorrected, 76 ^{k}E, Z = 4.35, MNI -36, -58, 31) while showing decreases in several other regions; the bilateral SPC (left: whole brain, $P = 0.001$, FWE-uncorrected, 224 ^{k}E, Z = 3.70, MNI -34, -49, 69; right: whole brain, $P = 0.001$, FWE-uncorrected, 198 ^{k}E, Z = 3.97, MNI 27, -58, 67), the left middle occipital cortex (whole brain, $P = 0.001$, FWE-uncorrected, 164 ^{k}E, Z = 3.68, MNI -32, -67, 18), the left superior frontal gyrus (whole brain, $P = 0.001$, FWE-uncorrected, 27 ^{k}E, Z = 3.42, MNI -18, 60, 1), and the right superior frontal gyrus (whole brain, $P = 0.001$, FWE-uncorrected, 26 ^{k}E, Z = 3.30, MNI 21, 9, 75).

To examine the relationship between structural changes and traits such as depression and impulsivity, we conducted covariate analyses involving the correlation of structural changes to BDI and UPPS-P scores. Of the 74 subjects that had filled out questionnaires, the BDI and UPPS-P scores were analyzed and correlated with whole brain group differences. Here, BDI scores positively correlated with volume in the left putamen (whole brain, $P = 0.001$, FWE-uncorrected, 371 ^{k}E, Z = 3.79, MNI 14, 23, -2), the left middle frontal gyrus (whole brain, $P = 0.001$, FWE-uncorrected, 371 ^{k}E, Z = 3.76, MNI -30, 14, 43), and the left paracentral lobule (whole brain, $P = 0.001$, FWE-uncorrected, 229 ^{k}E, Z = 3.91, MNI -14, -25, 57). On the other contrast, BDI scores negatively correlated with volume in the left IPC (whole brain, $P = 0.001$, FWE-uncorrected, 266 ^{k}E, Z = 4.06, MNI -44, -42, 40), the right middle temporal gyrus (whole brain, $P = 0.001$, FWE-uncorrected, 252 ^{k}E, Z = 3.78, MNI 37, -42, 13), the right superior parietal cortex (whole brain, $P = 0.001$, FWE-uncorrected, 105 ^{k}E, Z = 3.58, MNI 18, -75, 58), and the left lingual gyrus (whole brain, $P = 0.001$, FWE-uncorrected, 30 ^{k}E, Z = 3.80, MNI 20, -76, -5).

UPPS-P scores positively correlated with volume in the right middle frontal gyrus (whole brain, *P* = 0.001, FWE-uncorrected, 191 ^{k}E, Z = 3.49, MNI 40, 29, 39) and the left middle occipital (whole brain, *P* = 0.001, FWE-uncorrected, 156 ^{k}E, Z = 3.77, MNI -30, -64, 21). UPPS-P scores negatively correlated with volume in the right precuneus (whole brain, *P* = 0.001, FWE-uncorrected, 131 ^{k}E, Z = 3.67, MNI 9, -59, 66) and the left rolandic operculum (whole brain, *P* = 0.001, FWE-uncorrected, 27 ^{k}E, Z = 3.50, MNI -45, 2, 13).

On an exploratory level, structural volume was investigated as a function of age. No regions of interest were found significant when positively correlating age across all subjects. On the other contrast, age was negatively correlated with volume in the bilateral SPC (left: whole brain, *P* = 0.001, FWE-uncorrected, 1,212 ^{k}E, Z = 4.78, MNI -36, -64, 54; right: (whole brain, *P* = 0.001, FWE-uncorrected, 1,166 ^{k}E, Z = 4.92, MNI 40, -55, 55), as well as the bilateral middle temporal gyrus (left: whole brain, *P* = 0.001, FWE-uncorrected, 2,937 ^{k}E, Z = 4.70, MNI -66, -10, 9; right: whole brain, *P* = 0.001, FWE-uncorrected, 1,970 ^{k}E, Z = 4.93, MNI 68, -10, -9), one of which, the bilateral SPC, was a region already identified significantly different in CSB subjects. The difference in this region can, at least partially, be explained by variation in age. To further examine if the age related change was driven one of the groups, a new analysis was made with the covariate interact with group factors, which revealed that age related changes were driven by the healthy volunteers.
As mentioned, CSB subjects had higher BDI scores than healthy volunteers. On an exploratory level, covariate analyses were conducted to determine whether this might be attributed to the volumetric increase found in the amygdala. This was done as the amygdala has previously been shown to be heavily involved in unipolar and recurrent depression (Drevets et al., 1992; Sheline et al., 1998; Hastings et al., 2004). There was found no such correlation between reported BDI scores as a function of changes in the amygdala.

Discussion

The scope of the present study has been an investigation of the spatial progression of structural brain change in CSB assessed using VBM. The main findings show (*1*) that CSB subjects have significantly increased volume in regions implicated in reward and addiction such as the VS and (*2*) the amygdala, as well as (*3*) significantly decreased volume in the left IPC.

These findings are placed within a limited literature in terms of previous studies in similar and other behavioral addictions. Among the studies observed and included in the present study, both convergent and divergent evidence exist, and are there are both strengths and limitations in this literature. In light of the existing limitations, we provide directions for future research in CSB.

To address the first main finding, altered reward processing in the VS has already been established in CSB when exposing subjects to sexually explicit stimuli as these subjects show significantly increased BOLD-responses in the VS during the processing of monetary rewards (Voon et al., 2014). The present findings of increased volume in the VS are in agreement with these results. This correspondence might indicate that our structural findings are related to functional alterations associated with excessive processing of rewarding stimuli. Furthermore, the findings of Koehler et al. show similar volumetric increases in the VS in pathological gamblers (Koehler et al., 2013) as well as a recent study in IGD also shows similar findings, as Cai et al. (2015) found an increase volume in the VS in IGD subjects. However, the study by Cai et al. also found a significant volumetric increase in the right putamen. As Kühn's (2014) study in non-patient consumers of sexually explicit material found a negative correlation between consummation and right caudate volume, this indicates different and bidirectional components of striatal volume as a function of CSB subjects and non-patient consumers, whereas striatal volume seems more unidirectional in IGD. In the study on healthy volunteers consuming sexually explicit material, Kühn (2014) showed a negative association between hours of reported consumption of sexually explicit material and GM volume in the right striatum (caudate) and left striatum (putamen). The present findings are indicative of another mechanism involved with CSB as the present study reveals an increased volume in the VS. This dissociation and the structural distinctions between non-patient and patient group points towards a rationale for the increase of the VS only as a product of excessive consumption of sexually explicit material, as this is not the case in non-patient groups consuming sexually explicit material. Future studies should aim to further demarcate the striatal changes taking place in CSB subjects and non-patient consumers.

The VS is known throughout the literature for its role in the expectation of and response to reward. This can be linked with a body of evidence suggesting the VS as a key component of the cortico-striatal motivational and reward processing system (Haber & Knutson, 2009; Ersche et al., 2012). It additionally has reciprocal connections with dopaminergic cells in the ventral tegmental area

(VTA). Previous studies in cocaine dependence have suggested that the increases observed may be caused by reduced endogenous dopamine availability in the striatum (Jacobsen et al., 2001; Ersche et al., 2011). Supporting this hypothesis, in cases where dopaminergic signaling is decreased, such as in patients taking D2 antagonists, basal ganglia structures are enlarged, whereas in patients taking medication increasing dopamine availability, like methylphenidate for attention deficit hyperactivity disorder, striatal volumes are relatively reduced compared to unmedicated peers (Keshavan et al., 1994; Corson et al., 1999; Bussing et al., 2002). In line with these studies, the greater VS volume observed in the present study may relate to altered dopamine signaling in CSB.

According to current neuroanatomical models, the VS might drive the impulsive behavior whereas the caudate and putamen might drive compulsive behavior (Fineberg et al., 2014). In the framework of the mentioned model, and converging with our results, CSB subjects would be considered more impulsive with the changes in the VS, whereas Kühn's study in non-patient consumers of sexually explicit material shows a negative correlation between consummation and right caudate volume and might indicate either a positive or negative correlation with compulsivity. Other studies have suggested that initial impulsive behaviors are associated with increased responses to salient stimuli as substances relevant to addictions and are mediated by the VS, whereas later and more habit-based stages are transferred from ventral to dorsal striatum (Everitt & Robbins, 2005). Future studies should address the properties of the relationship between the VS, caudate and putamen, along with how these relate to impulsivity and compulsivity as well as the divergent results that have appeared in preliminary studies.

Results on studies in alcohol have also shown structural alterations taking place in the VS. For example, Makris et al. have shown a volumetric decrease in the VS as a result of alcohol use disorder (AUD) (Makris et al., 2008), whereas Howell et al. (2014) have shown an increase in binge drinkers (BDs). The present findings point towards unidirectional long term structural alterations of excessive behaviors in CSB, both convergent and divergent with research in AUD and BDs, despite both being regarded as behavioral addictions. This may be indicative of a differing role of the VS across these behavioral addictions. Therefore, future studies should try to further delineate the detailed relationship between different behavioral addictions and striatal morphology.

Whether local structural brain changes in the VS in CSB subjects are preconditions for or a consequence of the maladaptive sexual behavior cannot be determined by the present study.

Prospective studies would benefit from further addressing this question. For example, on a cellular level, the observed higher local GM volume might be due to various processes such as hypertrophic or hyperplasic processes or increased extracellular volume. These measures cannot be determined by our methods. Nevertheless, previous neuroimaging studies have shown that extensive experience with certain behaviors may alter brain activity during performance (Haslinger et al. 2004) and enlarge the associated brain structures as a consequence hereof (Granert et al. 2011). This may be explanatory of the present finding of a volumetric increase in the VS.

To address the second main finding, In IGA, results are divergent with the present findings as Lin et al. (2015) showed that IGA subjects have decreased volume in the amygdala. As with the structural brain correlates for AUD, the structural brain correlates of CSB point towards opposite structural long term effects of excessive behaviors than of that in IGA. This has been shown in several studies where volumetric properties have been assessed on alcohol dependence (Sullivan et al. 2005; Wrase et al. 2008). Also, Makris et al. found volumetric decreases in the left amygdala, divergent with present findings and further supportive of a theory of different neural mechanisms involved across alcoholism and CSB. In a recent CSB study by Voon et al. using functional Magnetic Resonance Imaging (fMRI), CSB subjects demonstrated greater activity in the right amygdala. Our results are convergent with this finding in that extensive neural activity associated with such behavior can enlarge associated brain structures over time (Granert et al. 2011). Future studies should aim to explain how this process envelops in CSB, as subjects show unidirectional change in both neural activity and structure in the amygdala as a consequence of exposure to sexually explicit material.

Throughout the literature, it is well known that the amygdala plays a crucial part in the processing of emotional control and management (Cardinal et al., 2002; Gottfried et al., 2003; Klüver, 1939) as well as the impairment of the amygdala leads to an increase in emotional perception (Barton & Aggleton, 2000). Also, within substance abuse, it has been shown that the amygdala plays a profound role (Hyman, Malenka, & Nestler, 2006). Less has been discussed about this region in the CSB literature. Consistent with prior studies showing comorbidity in hypersexual disorder and paraphilia-related disorders (e.g. anxiety disorders, substance abuse, sexual dysfunction, mood disorders or impulse control disorders), the present results of increase in the amygdala may be associated with impaired emotional control and management (Kor et al., 2013; Kafka & Hennen,

2002; Black et al., 1997; Raymond et al., 2003). Hence, this may be explanatory of the present study's finding of a volumetric increase in the amygdala.

Furthermore, an exploratory covariate analysis was performed on BDI scores to see, whether depression scores could contribute to the explanation of the amygdalar changes seen in CSB subjects as previous studies have shown a relationship between the amygdala and states of depression (Drevets et al., 1992; Sheline et al., 1998; Hastings et al., 2004). No such correlation was found. Amygdalar changes associated with depression have previously been reported as a volumetric reduction. The present study's results show an increase in the amygdala, placing the findings in the context of supporting an alternative explanation of the amygdalar changes in this study that are different from those seen in depression. Future studies and replications should aim to further assess which components of CSB are driven by amygdalar changes and what these mean.

To address the third main finding, convergent with our results, two studies where cortical thickness analysis has been assessed in pathological gambling and online gaming addiction (OGA), there has been found cortical thinning in the IPC (Grant et al., 2015; Yuan et al., 2013). This may imply that across PG, OGA, and CSB, similar neural mechanisms may take place for excessive and addictive behaviors that are converging in the long term structural brain effects. Previous studies with findings in the IPC have shown the importance of this region's importance for inhibitory control (Garavan et al., 2002), cue-elicited cocaine craving (Grant et al., 1996) and gaming craving (Ko et al., 2009). Our findings of a volumetric decrease in this region might be indicative of the IPC as being involved in inhibitory control in CSB subjects, thereby contributing to the explanation of the compulsive and repetitive behaviors that CSB includes. Future studies should aim to further establish the grounds for this assumption.

Limitations

Although the present study has revealed several important findings underlying the structural brain changes associated with CSB, several of the study's limitations should be considered. First, future studies would benefit from an even larger sample size than the 23 CSB subjects in this study. Second, ASES scores were not obtained for a sufficient amount of participants for group comparisons, which would have been interesting to correlate with measures such as the increased and decreased volumetric regions found in previously mentioned studies.

Similar to other behavioral addictions (Leeman & Potenza, 2013; Potenza, 2009), the etiology of the structural abnormalities among the CSB subjects cannot be addressed in this study. The effects may be related to differences in neuromaturational trajectories and sensitivities as well as to the level of neuroplasticity associated with the individuals' age of onset of consummation. The observed differences may be related to pre-existing dysfunctions or structural abnormalities, and can be determined by a multifaceted array of variables such as environmental or genetic factors, as well as a result of the effects of CSB. These possibilities, though, are not mutually exclusive. A fundamental problem in studies like the present consists in the lack of pre-morbid measures on the regions shown to be structurally changed. This means that the present study cannot make inferences about causality in relation to CSB.

Future studies should aim to assess longitudinal measures on these changes as the literature would benefit of controlling for the gap between state and trait tendencies and pre-morbid structural brain correlates. For the continued uncovering of morphological alterations affected by or preceding the initiation of CSB, it would be ideal to monitor psychosocial and environmental variables as these are undeniably intertwined in the etiology and symptomatology of CSB.

Conclusion

Twenty-three CSB subjects and 69 age-matched male healthy volunteers were scanned using magnetic resonance imaging. After analyzing and assessing the scans using VBM, CSB subjects displayed significant volumetric increases compared to healthy volunteers in regions such as the VS and the amygdala and showed volumetric decreases relative to healthy volunteers in the left IPC. In conclusion, CSB subjects demonstrate structural brain changes as a function of their behaviors. This may be indicative of neural correlates for the detrimental effects that CSB subjects report of their behaviors. However, there are different possible interpretations to these volumetric alterations, and the present study has certain limitations in that it cannot make causal inferences about effects of CSB. Therefore, future research in CSB should aim to further delineate the relationship between CSB and the structural brain alterations associated with this condition that is not yet recognized by the DSM-5 as a clinical diagnosis. This could be further assessed through the use of longitudinal measures on both environmental and genetic factors.

3. Thesis Part B – Research background and significant theoretical perspectives on the problem statement

Part A of the thesis was comprised of a scientific article that had the intention of delineating a relationship that unfolds between CSB and the neural correlates of this phenomena, or in other words, between the mental and the physical. The neuroscientific field is dominated by a natural scientific and empirical approach, which seeks to assess the relationships between the brain and certain phenomena and behaviors. This is highlighted in Part A of the thesis in terms of assessing the neural correlates of an addiction such as CSB. This is of interest because there must exist an explanatory relationship which is able to connect the mental and physical. This relationship, however, the field of neuroscience has yet to explain or treat as an existing problem.

In order to problematize this relationship between the mental and the physical, an internal approach through the empirical study is not sufficient. Rather, this must be approached externally and theoretically from key problems that such a study leaves unaddressed. Part B of the thesis seeks to explain this relationship, as neuroscientific data in itself merely incorporates correlation, and not explanation, of this relationship. Thus, if we are to usefully discuss the relationship between mental and physical levels of description, then necessarily, we must seek to explain it. This especially applies to the present topic of addiction, as such a state develops through learned behavior, thus being in need of a causal explanation in order to understand how such a state arises.

This explanation is what will be sought provided in Part B of the thesis. Hence, this part of the thesis will critically highlight two categories of problems that arise out of the scientific study in Part A of the thesis; an ontological and a methodological one. The ontological problem relates to the type of explanation that can be used to understand the relation between the mental and the physical. The methodological problem relates to how it is methodologically possible to measure the content of the mental and the physical. Thus, current problems in philosophy of mind and neuroscientific methodology will be presented through a discussion on the metaphysics of the mind addressing reductionism and causality, and subsequently through relevant methodological considerations. These discussions will be joined together in the addiction model, an explanatory model that seeks to problematize this relationship. Hence, Part B of the thesis will delve into these problems in order to create an overall model that seeks to explain addiction as a phenomenon said to hold both mental and physical properties, through its relationship to attributed effects both from society and from the neural correlates, which have been examined in Part A of the thesis.

3.1 Historical antecedents of cognitive neuroscience

The following section of the thesis will provide a brief historic outline of the neuroscientific account of human behavior and will facilitate an investigation and elaboration on the different ways to grasp the idea of the brain as being both localized and distributed. This will be done through applying the historical advances in neuroscience to the results from Part A of the thesis. This will be a step in the investigation of how and why these levels of explanation can be said to co-exist in terms of both neuroscience and situated cognition, and the problems and potentials associated with it. The section includes an overview of the first indications of the brain-behavior relationship, scientific forerunners of cognitive neuroscience, and with relevant references to Part A of the thesis.

The term cognitive neuroscience was introduced in the late 1970's (Gazzaniga, 2009, p. 2). It was the culmination of the conclusion from both neuroscientists and psychologists that there is more to the brain than the sum of its parts, and in that the brain must enable the mind, which had been discussed long before the history of psychology. This way, these two scientific fields were coming together as neuroscience was in the need of the theories of psychology of the mind, and that psychology was in the need of a more elaborate account of the human brain (ibid., p. 16). The issue of whether the mind is enabled by the brain working together as an integrated whole or whether the brain is working in specialized regions independently, is a general question and a central issue of most of modern research within cognitive neuroscience. Over the years, the dominant theory has changed profoundly and is still admitted to change as the knowledge of the brain expands.

But the story of the brain-behavior relationship began long before. In the middle of the 17th Century, neurologist Thomas Willis would be the first to link specific brain damage to specific behavioral deficits (ibid., p. 2ff). Willis did this by treating people throughout their lives and autopsying them after their deaths to tease out how changes in their brains might have affected their behavior (ibid.). Willis would later theorize how transfer of information in the brain took place, which he termed neuronal conduction (ibid). In the differentiation that he found between the human and animal brain, he theorized that the volumetric difference of the cortex was responsible for human intelligence. Here, Willis' view is compatible with the results from Part A of the thesis, in how brain regions change as a consequence of certain behaviors. This way, Willis foresaw the line of inquiry for cognitive neuroscience which still holds ground today in showing how isolated brain damage affects behavior.

In the beginning of the 19th Century, a localizationist view of the brain became more profound. Franz Joseph Gall was one of the first to declare the existence of around 35 functions that the brain was organized around; this scientific discipline was called phrenology (ibid.). These functions were said to range from basic cognitive tasks such as language and color perception to more abstract capacities such as hope and self-esteem, and were thought to be supported by specific brain regions (ibid.). According to phrenologists, an increase in brain size would cause bumps on the head, which made it possible to characterize a person on behalf of skull shape and size through careful analysis. Here, Gall would claim that addiction would be correctly answered through functionally and specifically locating a single region that is changed of the previously claimed 35 brain regions. Clearly, this would be a mistake as is presently known, even though Part A of the thesis seeks to localize, which regions have been volumetrically changed as a behavioral consequence of CSB.

As neuroanatomists delved deeper into the understanding of the structure of the brain in the late 19th Century, Korbinian Brodmann analyzed the cellular structure of the brain and found a startling result; that the cortex could be divided into 52 distinct regions (ibid., p. 7). How cells differ in regions is called cytoarchitectonics. Soon after this, several neuroanatomists discovered that these different areas were also functionally distinct from each another. For example, the characterization of the primary visual cortex (Brodmann area 17) as being distinct functionally from area 18, demonstrates the impact of this divided perspective of the brain. Just as the ventral striatum is localized as Brodmann area 34, at the time of Brodmann's discovery in the 19th Century, the results from Part A of the thesis would have not been likely to entail today's distributed perspectives on brain functioning, because of this localizationist view being heavily dominant at the time.

At this time, though, not all scientists believed in this localizationist view. In the early 20th Century, an Italian neuroanatomist and future Nobel laureate, Camillo Golgi, found a way to permit full visualization of single neurons (ibid., p. 8). This rather groundbreaking method led Santiago Ramón y Cajal to extend Golgi's findings and to tease out that neurons were discrete entities. Golgi had believed that the brain was a continuous mass of tissue that shared a common cytoplasm but here, Ramón y Cajal was the first to identify the unitary nature of neurons as well as their transmission of electrical information taking place from the dendrites to the axonal tip (ibid.).

As the 20th Century progressed, this sharper localizationist view became mediated by scientists who saw both that particular neuronal locations serve independent functions, and that at the same time,

networks of these locations and interactions between them shape an integrated view on the behavior that humans exhibit (ibid.). This way, scientists have come to believe that the knowledge of parts such as neurons and brain regions must be understood in relation to the whole brain; the mind. A later section of this Master's thesis will contribute with a discussion of this perspective.

As it appears through the examples provided in this section, the historical antecedents of neuroscience would view the brain-behavior relationship from entirely different perspectives throughout the scientific advances in history. This has relevance to subsequent chapters, as localizing neuroscientific data will be used in relation to, how we are to understand the relationship between the mental state of addiction and the neural correlate of that state.

3.2 Historical antecedents of situated cognition

The following section of the thesis will provide a brief overview of the background from situated cognition that has contributed to situated cognitive accounts on human behavior. The section will include an overview of systems thinking and systems theory, as well as a non-systems thinking perspective brought about by research in artificial intelligence (AI). Finally, the section will present the scientific forerunners of situated cognition as well as potentials for scientific advances in this view. This introductory outline of accounts from situated cognition of human behavior will be used to facilitate an understanding of, why and if this account can co-exist with a neuroscientific one.

The central enterprise in systems thinking is studying phenomena in a holistic way and understanding causal dependencies and emergent processes as comprising the whole system (Clancey, 2009, p. 12). This could be both artificially in a PC program, naturally in living organisms, culturally in societies, and conceptually in concepts. Here, the whole system is defined as the dynamic and complex whole within an environment (ibid.). In distinguishing parts from the whole, systems thinking does not reject reductionism. Rather, it strives to show how the whole system makes the parts consist of what they do and vice versa. In this framework, an example could be considered such as the 2010 opening of the prominent building, the Burj Khalifa in the United Arab Emirates. The building has become defining for the country's expression to the rest of the world as being rich and cultivated. This way, the Burj Khalifa can be said to represent both the meaning of the nation (the whole) and of the building itself (the part), and how the building would

both be contained in the United Arab Emirates and be a symbol for the country as a whole. Systems thinking also views the parts from different disciplinary points of view (ibid.). For example in building the Burj Khalifa, agents could view the construction of it in terms of an architectural system, an economic system, a cultural system, and so on. In this way, different views frame the construction of the building and produce different attitudes of parts and its causal processes. As will be addressed later, this relates to discussions on reductionism and causality.

Systems theory, on the other hand, is an extension of the idea of systems thinking, and became influential especially in the social and behavioral sciences (ibid., p. 13). It is concerned with the dynamics involving interdependent relationships. An theory derived out of systems theory is the development of connectionism in artificial intelligence research, such as McClelland's model of parallel distributed processing (PDP) and its relation to theories of complex adaptive systems (McClelland, 1988). In such a paradigm, these dynamic interdependent relationships would manifest as how memory and information retrieval is seen as a reactivation of neurons that were active at the information encoding, thereby being dynamic, yet interdependent.

In systems theory, the term complex system refers to a system whose properties cannot be fully explained by linear interactions and their parts. An example of such a non-linear system is the concept of emergentism; a central feature in complex systems in analyzing human behavior (ibid.). Here, emergentism refers to, how more complex phenomena such as human behaviors and patterns arise through interactions of more simple elements, to which the effects are non-linear, or put in a different way, to which more simple elements do not exhibit the properties of the complex ones. As will be seen, the concept of emergentism, which are applied in systems theory, will be facilitating for a discussion in the following chapters. Another example could be the concept of feedback loops, and how both positive and negative feedback relations are found in complex systems (Clancey, 2009, p. 13). Here, an example from cognition could be the causal couplings that occur subliminally in processes of conceptualization and perception, and consciously as agents reflect on interpretation and actions. Also here, situated cognition reveals these non-conceptual and non-linguistic aspects of these feedback relations, and highlight conceptual aspects that relate to social relations (ibid.). An example could be to reduce, how different parts of the brain operate when expecting and experiencing reward, and how both facilitatory and inhibitory functions in the brain are caused by effects that are not reducible to its physical base properties, contrary to its social dependencies. This point will be much further elaborated in later sections of the thesis.

The emergence of AI was brought about in the 1950's as a non-systems thinking perspective, and is recognized as a revolutionary step within the understanding of psychology and even the nature of science as this movement became an important contrast to behaviorism (ibid.). With a reductionist process theory, it conflicted with the idea of situated cognition, and Newell and Simon (1972) explicitly contrasted the idea that behavior could be fully explained with no reference whatsoever to unobservable internal states (p. 9). The founders of AI, though, are criticized of viewing cognition as fully explained by internal states that can be reduced into smaller structures and components (Clancey, 2009, p. 13). This was an opposite claim than that of situated cognition, in which aspects of cognition is perceived to be happening in an agent's external environment. In the computational metaphor that followed AI, the study of intelligence was hence shaped in a way so that models were required to accurately describe theoretical understanding (ibid., p. 14). During the three following decades, AI got hold of a position that cognition was not distributed, and that culture was considered as a collection of knowledge rather than a complex system difficult to disentangle. In AI, the reductionist theory would claim that knowledge consisted of calculable discrete elements and relations, and the computational metaphor suggested that knowledge was simply assembled from previous learned facts and rules, which would reinforce the system. Here, system thinking was incompatible to raise influence in the period due to the fact that it would threaten the AI paradigm's apparent success in explaining aspects of mental functioning. This could be thought to have been facilitative in the scientific trend at the time being mostly on the grammar-based theories such as understanding aspects of speech recognition, text comprehension, object recognition and problem solving. Here, to return to the connectionist approach, this was the theory most compatible with systems thinking in that it originated in early networking modeling that also inspired the emergence of AI (ibid.). This way, AI prompted advocacy of reductionist explanation of mental phenomena.

As a defining moment for the modern view on situated cognition, according to a study by Roschelle and Clancey (1992), cognitive processes are causally social and causally neural at the same time, as they claim that an agent is both a part of society and that learning has other causal effects on the brain (p. 435). Here it is argued that representations are meaningful in a shared perceptual space as soon as agents engage with one another in spoken and written language as well as in social context. On behalf on their social experiment designed to investigate learning in a social context, and through the task of finding a solution to a visual task, it is shown how learners are initially uncertain about what the task of the experiment is, about the placement of representations in the task, and

how to express the relationship between the different components of the task (Roschelle & Clancey, 1992, pp. 437-440). What Roschelle and Clancey claim to show is how agents coordinate conversational and perception-action processes to maintain mutual understanding and task activity as well as how perception, language, and gesture are all used to construct shared meaning of the task (ibid., p. 447). In a broader perspective, they argue on the basis of their experiment that learning to distinguish basic tasks equivalent of everyday activities requires of agents to actively engage in context relevant exchanges, such as simultaneous coordination of perception, gesture and language (ibid., p. 450f). As will be seen, this theory on how meaning is constructed relationally, is related to a discussion on the situated perspective on the mind, which will be addressed later.

One way of understanding the grounding of situated cognition in these different aspects of cognition is seen in systems thinking, in that it seeks to reveal contextual effects that cannot simply be attributed to environmental 'factors' or 'input' (Clancey, 2009, p. 16f). A way to understand the term of a situated process is that the system operating cannot be understood strictly as localized within one level of analysis, and that cognitive processes cannot be reduced to pure neurological mechanisms, and that they cannot be purely conceptual on the other hand. Rather, what an agent experiences can be said to be an ongoing product of a coupled causal relationship, of both the entity being studied and its context, be it neurological, conceptual, psychophysical, or interpersonal (ibid.). The term 'causal' is important in this context and will be elaborated in later sections.
Similarly, situated cognition views human knowledge and behavior not as definite objects, with examples such as that they arise conceptually in the example of a thought; that they vary within different areas of expertise; that they are socially reproduced through learned practice; and that they are transformed by agents and groups of agents unique in their own perspectives (ibid.). This will be further addressed on behalf of, whether such perspectives can be granted significance in discussing them against an oppositional view.

In summary, situated cognition developed not as a discipline within either systems thinking or AI, but as a theoretical movement. This was proclaimed through these disciplines, which were defining of the 20th Century in psychology. As mentioned, these accounts of the situated cognition of human behavior will be used in order to discuss, whether it can co-exist with a neuroscientific one. This will be addressed in the following two chapters, which discuss the phenomenon of addiction related to the ontological problem, which Part A of the thesis leaves unaddressed, and that includes a discussion of the metaphysics of the mind and concepts such as reductionism and causality.

4. Ontological considerations – the metaphysics of the mind

In this part of the Master's thesis, what will be in focus is the first of the two problems that are to be addressed in Part B of the thesis. This relates to the ontological problem, which is why current philosophical thoughts on the metaphysics of the mind will be discussed in relation to the problem statement. This will be discussed on the premise that, in order to address how and if we can speak of the co-existence of two causal relationships, it is necessary to turn towards a discussion of certain concepts within the philosophy of the mind that can treat the ontological problem in Part B of the thesis. Although many philosophical positions exist on these issues, a key framework by Jaegwon Kim will be used in the following discussion, supplemented by his contemporary critics. It is important to note this, as there exist many positions, one of which is a prominent one by Kim. Therefore, only Kim's framework will be discussed, due to limitations on the length of the thesis.

Undeniably, a societal shift is taking place in the availability of sexually explicit material. Not merely on the Internet, where endless varieties of this material are available, but also in the media, we are exposed to certain degrees of this. But why is this said to have distinct influence on individuals, and what is its causal role in explaining the emergence of a phenomenon such as CSB?

The answer to this question is ambiguous and hangs on an encompassing philosophical discussion. If we are keen to accept that there exists a facilitative, and separate, role of society from that of a physical explanation of how a phenomenon such as addiction arises, we are stating that there is more to the effects of society on human behavior than the sum of its parts. What is meant by the sum of society's parts is that there is more to society's impact on our behavior than reductive statements such as that society consists of individuals, which can be reduced to interactions of biological mechanisms such as complex neural networks, their molecular interactions, and in the end their physical base properties. In order to assess this ontological problem, a discussion on the metaphysics of the mind and of concepts such as mind-body supervenience, mental causation, reductionism and emergentism will be brought forth. A discussion of the mind-body problem will be addressed first.

4.1 Mind-body supervenience

In '*Mind in a Physical World*', Jaegwon Kim raises an argument of the metaphysics of the mind and addresses the mind-body problem (Kim, 2000, p. 7). An analogy to the mind-body problem can be thought of as a lack of examination in delineating the relationship between mental properties and the brain, out of which mental properties in the form of thoughts arise. As such, in the mind-body problem, we are confronted with the problem of, whether there is more to the mind and its component mental properties than the mere physical properties that it consists of. Here, Kim raises an argument of strong mind-body supervenience, a philosophical concept that has its roots in the philosophical strand of physicalism and has standardly been taken as a relation between two sets of properties, which Kim describes as follows:

> Mental properties supervene on physical properties, in that necessarily, for any mental property *M*, if anything has *M* at time *t*, there exists a physical base (or subvenient) property *P* such that it has *P* at *t*, and necessarily anything that has *P* at a time has *M* at that time. (Kim, 2000, p. 9).

To provide a directly translated example: "*If a person has the experience of being addicted, then necessarily, it must be the case that this person instantiates some physical property, in the form of a neural response, such that whenever this person would instantiate this exact physical property, the person experiences a state of addiction*".

By this, Kim states that these high-level mental properties, *M*, are supervenient, or dependent upon the lower-level properties that they consist of (ibid., pp. 18-27). An addition to the argument is that of microindiscernibility; that if *M* is a mental property had by something, *x*, then any *y* that will be microindiscernible from *x* will also have *M*. In this framework, Kim argues that mental properties are macroproperties supervening on physical microproperties. However, Kim argues that the stated form of mind-body supervenience is merely an instance of mereological supervenience, which refers to the logical order of the natural sciences, and that it merely describes the determination of a relationship, and not an explanation of itself. This is to say that *x* may supervene on *y*, and in other words that *y* determines x, without having any idea of the causal explanation for this, or why *x* should arise from *y* and not *z* (ibid.). Hereby, it is also implicitly stated that a reducible or mereological supervenience of the mental on the physical will not give promise to an intelligible account of the reason for, why or if mind-body supervenience holds.

However, Kim states, certain limitations on the philosophy of mind-body supervenience exist. For example, given that mental property *M* is supervenient on a certain physically mereological order *O*, several questions remain unanswered such as, whether *M* is reducible to *O* in some appropriate sense; whether it is possible to explain *why* something has *M* in terms of its having *O*; whether the *O*-*M* and other such supervenience relations are further explainable; and whether supervenience relations must be taken fundamentally (ibid.). These questions seem relevant, yet independent of the question of, whether *O* is a microphysically characterized property that *M* arises out of. To determine this, another discussion is needed.

As the example of the first supervenience argument instantiates, mind-body supervenience should occur in any system where a mental phenomenon occurs. In the previous example, however, being in a state of addiction is used as the subjective experience of an agent, and it is not specified, whether the mentioned state is internally or externally invoked. This detail is of primary relevance to the thesis. What if, say, the example was as follows:

> If a person has the experience of being addicted and reports this as being attributed to the agent's environment constantly making available and exposing sexually explicit material, then necessarily, it must be the case that this person instantiates some physical property in the form of a neural response, such that whenever this person would instantiate this exact physical property, the person experiences an addiction and reports this as being attributed to the environment constantly making available and exposing sexually explicit material.

This change to the example highlights a potential discussion of Kim's philosophy on mind-body supervenience and of, whether the supervenience argument is still just as generally applicable, regardless of which mental property the physical property is instantiated by, and whether the mental always supervenes on the physical regardless of what properties the mental hold.

This argument stands or falls on a question different from supervenience that applies to the philosophical concepts of mental causation, emergence and reductionism. The exemplification of a mind-body supervenience relation of *M* being a mental property that carries a gradual dependence of *x*, is an example exerted on a mental phenomenon depending on, or co-occurring with, something as dynamical and amenable to change as a societal tendency; something that occurs at a most abstract level of description. In order to discuss whether such a mind-body supervenience relation can hold, another of Kim's conceptual problems needs to be addressed; that of mental causation.

4.2 Mental causation

According to Kim, the principal problem of mental causation is that it arises out of the 'exclusion problem' that also incorporates the argument of supervenience. This in integrated in the notion and question of mental causation that is: "[…] *how is it possible for the mind to exercise its causal powers in a world that is fundamentally physical?*" (ibid., p. 27). This question relates to the thesis' examination of, whether there is a way of assessing the ontological problem of reductionism and causality in the explanation of the emergence of CSB.

The idea of mental causation seems evidently human and intuitive in that the possibility of human agency requires of our mental states such as our intentions, desires and beliefs, that they are real and therefore have causal effects in our physical world (ibid., p. 31f). This can be put aside with the notion in psychology of top-down control. Also, it is universally believed that human knowledge requires the reality of mental causation, in that our perception, our window to introspect on the world, requires the causation of experience and belief in the physical world around us. This way, arguably, mental causation seems necessary for the belief in our existence. Even more fundamentally, Kim argues, it seems that the validity of psychology as a special science that generates laws and explanations of human behavior, depends on the reality of mental causation in that mental phenomena necessarily must function as indispensable links that can causally explain physical behavior (ibid.). A philosophic critic of Kim, Jerry Fodor, states his belief this way:

> If it isn't literally true that my wanting is causally responsible for my reaching, and my itching is causally responsible for my scratching, and my believing is causally responsible for my saying [...] if none of that is literally true, then practically everything I believe about anything is false and it's the end of the world. (Fodor, 1989, p. 156)

As this statement says, and if mental causation is merely an illusion, then the world that Fodor points towards being a world of agency and cognition, is a world that will end, if the problem of mental causation holds (Kim, 2000, p. 32). It is also argued that the problem of mental causation stands on three component problems: the first being that of anomalous monism stating that there exist no causal laws about psychological phenomena; the second being that of computationalism and content externalism stating that 'syntactic', intentional causative properties in behavior are non-relational an intrinsic whereas 'semantic', representational properties are relational and non-causal; and the third and most relevant for this thesis being that of causal exclusion (ibid., p. 35ff). This third problem of causal exclusion is stated by Kim as such:

> To acknowledge mental event *M* (occurring at *t*) as a cause of physical event *P* but deny that *P* has a physical cause at *t* would be a clear violation of the causal closure of the physical domain, a relapse into Cartesian interactionist dualism which mixes physical and non-physical events in a single causal chain. But to acknowledge that *P* has also a physical cause, *P** at t is to invite the question: Given that *P* has a physical cause *P**, what causal work is left for *M* to contribute? The physical cause therefore threatens to exclude, and pre-empt, the mental cause. (Kim, 2000, p. 36f)

Posited another way, if it is possible to distinguish real causal processes from the non-causal regularities that are observed as apparent causes, a fruitful position will have been reached.
A central point to Kim is that in order to instantiate a supervenient property, one must cause its base property to be instantiated (ibid., p. 42f; 48f). As an example of pain, to relieve a headache one might take aspirin, which would be equivalent to causally intervene on a neural state, on which the headache supervenes, and where sequences of neuronal firings are in fact the cause of the pain. This way, physical pain can cause the desire, intention or mental state to relieve the pain and hence take aspirin. Another example that involves possible convergent causal chains can be stated in explaining the reason for a bull's aggressive behavior in a Rodeo show (p. 52f). Here, the cape used to stress the bull would hold two properties for invoking aggression in the bull; one being its redness and the other its provocative movements. The redness of the cape would then be the first-order property, and the provocativeness the property in second-order. In separating these, however, Kim argues that one could favor overdetermination; the idea that a single effect is determined by multiple causes at once, anyone on its own might be sufficient for the effect to be caused. This would be a mistake, Kim argues, as the first-order property of the cape's redness in itself would be sufficient in the explanation of the bull's aggression. If this is true, no further causal role could matter in spite of the cape's provocative movements. Kim states that still, the exclusion problem persists, if recognizing that the second-order property is causally efficacious in addition to its enabler, its redness (ibid.). This way, as long as these properties would be recognized as separate events, the exclusion problem would persist.

Despite this line of argumentation, suppose taking in examples including extrinsic factors such as the desire, intention or mental state to change a socially occurring behavior. Then, another question would arise. Even if mind-body supervenience holds or is merely accepted, its argument may be challenged as such socially contingent phenomena are abstract and heavily debated on the contents of their properties. Whether or not extrinsic factors by themselves are facilitative of certain behaviors, whether they are reducible to the sum of their parts, or whether these hold emergent

properties, depends on another challenge. That is, a challenge of teasing out, which kinds of properties such phenomena hold, and whether these can impose additional effects and distinct causal roles on phenomena. This challenge relies on a discussion of reduction and emergentism.

4.3 Reductionism and emergentism

In facilitating the discussion of reduction and emergentism, an example of an emergent event will be used: a desire for a glass of water can cause an agent's body movement towards a water tap. This would clearly be a case of mental causation; a desire which causes a bodily movement that supervenes on the neurophysiological properties of neural signals and muscle groups at a lower level of description (ibid., p. 64f). With a neural event being a lower level in the line of reductive explanation, there seems reason to think that this neurophysiological causal explanation also exists. From this example, Kim raises a question on the relationship between both the physical and the intentional explanation; one that invokes a neural state as a cause of bodily movement; and one that invokes the desire for water, as a cause of the same event. Kim denotes some possible accounts of these explanations as being the causes of the event: (*a*) each one is a sufficient cause and the effect is causally overdetermined; (*b*) they are each necessary and together make up the sufficient cause; (*c*) one is part of the other; (*d*) the causes are in fact one and the same but given under different descriptions; (*e*) the mental cause is in some appropriate sense reducible to the physical; and (*f*) the mental cause is a resulting cause depending on the physical cause (ibid.).
The problem stressed is that of causal exclusion; that the presence of two causal stories each claim to offer a full causal account of the event. This creates the following discussion to find an account of, how the two purported causes are related to each other.

This section stands on the question of, whether or not the mental is amenable to the kind of functionalization required for reductive explanation, or if the mental resists such functionalization. Here, a clear definition of functionalism must be given. Kim describes functionalism as the idea that mental properties are functional properties described at a higher level of abstraction than its constituent components such as its physicochemical bases (ibid., p. 3). The properties are specified as their causal roles between sensory input and behavioral output. Important here is that the physicalist kind of functionalism takes physical properties such as neural states as the only possible enablers of these causal roles (ibid., p. 19). This way, the mental is seen as a distinctive domain that

can be investigated and scientifically reduced. The relevant question for the thesis, however, is whether this distinctive domain of the mental is scientifically reducible to its physicochemical constituents, or whether any emergent properties of the mental exist.

In the discussion of reductionism, a central theory is that of the prominent philosopher Ernest Nagel's model of reduction. In this model, so-called 'bridge laws' provide the essential reductive links between a given theory targeted for reduction and the base theory, which is what enables the derivation of the target theory from its reducer (ibid., p. 90). Kim points towards a necessary breakdown of this law when explaining the reduction of the mental to the physical. When bridge laws are used to explain links between target and base theory, then necessarily, complete target and base theories are needed in order for these to be used for scientific reduction (ibid.). However, it is the case with psychology that no such complete theory of the causal link between the mental and the physical exist. Hence, no such Nagelian scientific reduction would seem possible; only a potential theoretical one. In the present interest, this means the one of mind-body reductionism, where the science of the mental, psychology, can be seen as the theory targeted for reduction, and the science of the physical, at this level of description neuroscientific research, as its base theory. And as Nagel's model cannot be applied to a precise law governing the science of the mental and its reductive base of neurobiology, another discussion is needed; that of functional reduction.

Kim's functional model of reduction states the necessity of enhancing bridge laws ($M \leftrightarrow P$) into identities ($M = P$), as these identities serve to answer an explanatory question about bridge laws; that the laws are instantiated because they are in fact the same property, and hence reducible (ibid., p. 97ff). However, if *M* and *P* turn out to be distinct and intrinsic properties, an identity of $M = P$ could never be reached, as the functionalizability is needed for reduction (ibid.). As an example, consider the functional construal of boiling water. It seems that once this property will have been functionally understood, as the capacity of a substance to heat up and reach a maximum temperature, it seems feasible that a reductive explanation could be formulated of why water has this power once this functional property of water exists. Here, Kim would seemingly argue that a strategy of similar traits should allow reductive explanations of biological and even social phenomena as well, as these properties can be perceived as second-order functional properties over first-order properties such as neural activity and transmission, and in the end, their physical base properties (ibid., p. 100f).

The examples above are clear in stating the need of a functional account of a phenomenon in order to make it reducible. The question is, whether or not all such phenomena can be functionalized and hence reduced. Clearly what Kim urges is this; that the functionalist conception of mental properties is required for mind-body reduction. If this is the truth in facing this discussion, then mind-body reductionism and the functionalist approach to mental properties stand or fall together (ibid.).

Consider a relevant example for the present thesis: how to tackle a biological phenomenon such as a second- or higher-order, addictive property occurring at a behavioral level and then reducing this property to a lower-order physicochemical property. This, in fact, is already sought executed in the thesis through the fact that the structural brain correlates of CSB have been assessed. In addition to this, consider another of the thesis' questions; why such a phenomenon can be explained at different levels of description; in terms of both reducing it to its first-order base property, and how at the same time it seems obvious, through the effects of society and the reports of patients, that very clearly, something more vast and dynamic is at influence, something perhaps 'third-order'. In considering this, we are faced with a property highly implicit in its nature, and severely difficult to characterize as a functional and hence reducible property, in which the challenge is not merely to reduce a second-order property to its base first-order property. Rather, it is to treat a second-order property, knowing that it is dynamically changed and shaped by a 'third-order' property at its most abstract level of description, and then attempting to make the property functionalizable in order to reduce it to its first-order physical base property.

Here, Kim acknowledges that the functionalization of qualia is the primary challenge for mind-body reductionism in comparison to the functionalization of intentionality (ibid., p. 102ff). This is stated in that the seemingly, distinct properties of intentionality can in fact be functionalized as seen with the abilities of computers to duplicate memory and information processing and hence aspects of intentionality. However, Kim defines qualia as the felt and phenomenal qualities of experiences that, if anything is, are resistant to functional reduction (ibid.).

To sum up the discussion so far, functional properties as second-order properties do not emerge new causal powers into the world, that is, they do not hold causal powers that go beyond the causal powers if their first-order realizers, and there are no problems associated with the causal powers of functional properties. This is indeed compatible with the urged model of reduction from Kim; that

reduction is functionalization, and if the mental is reducible to the physical, the problem of mental causation would thus be solved. However, it is those mental properties, if any, that resist functionalization, which instantiates the problem of mental causation. And as long as there may exist non-functionalizable mental properties such as qualia, the problem will remain.

At this step we must revisit this supervenience argument. As Kim points out, in the case of supervenient psychological properties, the problem of mental causation is regenerated in that both the causal psychological properties such as mental properties and the physical base properties such as neurobiological properties, are had by the agent (ibid., p. 117). This way, both the causal role of the mental and that of the physical seem explainable as distinct causal powers. Because of this fact, a separate causal role must be granted to the physical properties at the higher level in that these causal powers are not had by any lower-level properties that constitute them (ibid., p. 118). The supervenience argument does not apply to such causal powers in that it only generalizes to functional non-mental properties, if any such ones exist (ibid.). Thus, if reduction essentially is functionalization, the problem of mental causation generalizes to all supervenient properties that are non-reducible to their base properties and that hence hold emergent properties.

One such reductive statement is to think that by quantifying over properties, it is not possible to create new properties any more than thinking that by quantifying over individuals we can create new individuals (ibid.). In stating this, reductionism seems difficult to endure when going from a derivation of supervenience on a closed system to an open and dynamic system. Suddenly it becomes clear that in order for mind-body reductionism to hold, these second-order, dynamic processes or properties held by society must be reducible to the sum of their parts, in the form of their physical base properties.

This leaves a dichotomous choice. The one choice is an embrace of all-encompassing reduction and hence functionalization of all mental properties, which, if true, would solve the problem of mental causation. In accepting this, an acceptance follows of all mental properties such as conscious experiences that seem to resist functionalization, are in fact reducible, although there seems no way to account for their causal powers within this reductionist and physicalist scheme. The other choice implies an abandonment of physicalism in favor of dualistic belief that will abandon strong mind-body supervenience. As things appear, if the choice falls on the physicalist scheme, either it is

possible to retain that mental properties are supervenient but yet irreducible and non-functionalizable and accept their causal irrelevance, or it is possible to deny the reality of these irreducible properties, either of which seem improbable. This means that the possibilities of physicalism seem to reinforce the idea of the mental as unguided and even non-existent. Here Kim believes that preserving the mental as part of the physical is the better choice, although he remains inconclusive on the dualistic position and the possibilities that such a position holds (ibid., p. 120). However, over the years, a series of other positions between these two extremes such as property dualism, anomalous monism and non-reductive physicalism are emerging. These positions will not be included in this section of the thesis. Moreover, in the next chapter, ideas from situated cognition will be discussed as an opposition to Kim's reductionist program.

4.4 Conclusions for chapter four and addiction model perspectives

On behalf of the scientific study and the ongoing theoretical discussion, addressing the ontological problem of the metaphysics of the mind will be summed up in this section. The purpose of discussing the ontological problem will begin a move towards a discussion of methodological considerations in order to create the addiction model. Hence, in this section, the arguments from Kim will be taken into account in terms of creating this model.

A primary question for the thesis is to discuss the relationship between a neuroscientific and a societal explanation of addiction. It seems inherently clear that both exert an influence, or that both can at the least be described as valid explanations. Given the supervenience argument presented in the present chapter, it does not make sense to divide or isolate the two above explanations, as the claimed effects of society will also affect the neural or physical state. Still, often a claim is held that a number of factors exert their influence. But if the supervenience argument holds, this can in fact be perceived as an intertwined phenomenon. This is so, as both mental and physical properties seem to exert influence on an agent, with these being connected through the argument. Thus, it does not make sense to speak of the two as being separate, and hence, society's influence can be said to exist or manifest also on a neural or physical level of description. On the contrary, if robust reductionism would hold, it would be sufficient to explain only the physical level; a story that could be one of the relationship between dopamine and addiction as a complete model of addiction.

This, however is contested on the present discussion, as addiction seems to be a state that holds both mental and physical properties. In acknowledging emergent properties of certain phenomena, what the supervenient relation means, is that the physical bases of addiction are not sufficient for creating the intended addiction model. Rather, it will address both mental and physical properties of addiction. This relationship can be stated in a question of, why people become addicted. Here, the scientific literature might say that there are both biological and societal causes for addiction, just as the thesis attempts to address this relationship. Given the granting of the supervenience argument, however, it becomes clear that it does not make sense to speak of two distinct, isolated and dichotomous causes, but rather to speak of a relationship between what appears to be of mental and physical significance.

The shifting societal tendencies should be perceived as something that undeniably would affect the psychological and hence neural properties. Furthermore, these neural properties are amenable to the environment's influence on the agent's personal history, cultural heritage, upbringing, et cetera. As a consequence of this, when we look at the neural properties, these must hold the properties of society's influence on the individual. In the further steps towards creating the addiction model, these considerations will be applied.

Lastly, it must be noted that the reference to society holding emergent properties cannot stand as the argument for anti-reductionism. Rather, it is qualia, or in literal terms what CSB subjects report, that seem to hold properties that are non-reducible in the explanation of addiction. Thus, if a complete reduction of mental to physical properties would be attempted, qualia is most likely what would remain irreduced. Of course here, the problem is that qualia is what defines the 'mind' being separate from 'body' in the first place, which is why the mind appears to be non-reducible. This is the anti-reductionist argument for the thesis in addressing Kim's reductionist program, and this discussion is separate from that of society's influence on creating an addiction, and only applies as an argument against Kim's reductionist program.

This step of creating the addiction model has pointed out that qualia is what prevents reduction. Hence, mental properties are attributed causal significance. This will shape the subsequent methodological discussion, which is considered necessary to address in order to create the addiction model. Before treating the methodological problem, the next chapter will address relevant situated perspectives on the mind, which relates to a discussion on causality rather than on reduction.

5. Alternatives to Kim – situated perspectives on the mind

If following Kim, a physicalist approach will be taken to understand the two sets of data; one being qualitative from CSB subjects claiming to be addicted and the other quantitative through measures of addiction assessed through neuroimaging methods. Through Kim's approach, both sets of data would be claimed reducible to their physical base properties. It is important to point out that there exist alternatives to this position, which is what will now be presented in greater detail through two points in the following chapter. One is a direct critique of Kim's reductionist program, the other an argument for a situated view of the mind, in which the first set of data is granted causal significance.

5.1 Criticism of Kim's reductionist program

As seen, the arguments presented in the earlier discussion stands and falls on the question of, whether second-order mental properties have causal powers of their own. For Kim, this simply seems impossible, as such properties cannot qualify for causal efficacy, and thus he proposes a program of functional reduction. The first step in this reduction is functionalization that should be able to replace the earlier mentioned bridge laws, which are nomological relations between phenomena at higher and lower levels of description.

Simone Gozzano criticizes this point of view in a review of Kim's thoughts in '*Second order properties – Why Kim's reductions does not work*' (2003). Here, he urges an example of bridge laws to argue against this reductive line of thought: "[…] *it is not possible to establish a one-to-one correlation* [*of bridge laws*] *because many entities or properties at a given level can be realized by type-different entities or properties at a lower level.*" (p. 6f).

Through this argumentation, the strategy of bridge law reduction will be used in an example of temperature as it can be reduced to 'mean molecular kinetic energy' (Gozzano, 2003, p. 6). This is possible as there exists a law-like correlation, stating that when the temperature in a given substance is *x*, its mean molecular kinetic energy is *y*. According to Kim's argument, once bridge-laws have been individuated, it is thus possible to substitute and hence reduce every occurrence of the reduced term, here of temperature, with its proper reducing one of mean molecular kinetic energy (ibid.). However, problems with such a line of inquiry exist in raising the argument of multiple

realizability. This is seen in Gozzano's statement above; that no one-to-one correlation can exist if multiple properties can realize the phenomenon. To elaborate on the example of temperature, in fact, according to Gozzano, temperature is identical to '*mean molecular kinetic energy*' in gases through the bridge-law connecting them, whereas they are different for solids, where it is identical to '*mean maximal molecular kinetic energy*' or in vacuum, where temperature is identical to '*blackbody temperature*' as molecules do not exist in a vacuum (ibid., p. 7). Thus, the bridge-laws connecting these aspects of temperature are different, and the bridge-laws for temperature are not of general but of local type, as there are multiple realizers for the phenomenon of temperature.

According to Kim, the way out of these troubling challenges for bridge-law reductionism is to substitute correlation with identities. The challenge here, according to Gozzano, is that this implies that a mental property *M* is reducible to physical property *P* (ibid.). This is where functionalization takes its role. Functionalization was earlier described as functional properties described at a higher level of abstraction than its constituent components, and so expressing a mental property in terms of causal roles and then comparing the roles with those of its realizers (Kim, 2000, p. 3; Gozzano, 2003, p. 7). And if these realizers have the same causal role as the property examined, the property can be identified and hence reduced. In this question regarding, whether all mental states are functionalizable, qualia or qualitative states, as earlier described, pose serious challenges for reductive physicalism (Kim, 2000, p. 102ff). According to Gozzano, in the case of qualitative states, a functional description and reduction is simply impossible to hold ontologically. He exemplifies this through a sip of wine, and the subjective position from where the wine is tasted. Here, the difficulty is that qualitative states are intrinsic, and depend solely on the individual (Gozzano, 2003, p. 7). From Kim's own perspective, he acknowledges that "[…] *if emergentism is correct about anything, it is more likely to be correct about qualia than about anything else*" (Kim, 2000 p. 103).

Thus, if qualia cannot be functionalized, not all mental states can be reduced. Now, a revisit to the potential semantic change to Kim's supervenience argument presented in chapter four regarding a gradual dependence of *x* due to society exposing *x*; if one would acknowledge that this subjective feeling of a gradual dependence stems from a qualitative state, it would follow that this state cannot be functionally reduced to its base set of physical realizers. Here, Gozzano would point out that the reductionist program seems to be limited solely to intentional mental states as some of these can be taken as functionalizable because their identity conditions can be stated in terms of causal roles (Gozzano, 2003, p. 7f). Kim, obviously, would disagree on this premise to be taken as an absolute

truth, although he acknowledges that functionalization is the only way in which it is possible to make sense of the causal powers of mental properties. This is where Kim argues that, at least in principle, mental properties can be reduced to physical properties. However, Gozzano sees a serious limitation to Kim's program in that he only shows that intentional mental properties are possibly functionalizable and thus reducible. Gozzano argues:

> Now, when a nomological identification is available, the kind of reduction that follows is epistemological, that is, is a reduction that applies only [to the] laws of nature and our knowledge of them in our actual world and in all other worlds in which the same laws hold. […] This is not at all metaphysical reduction, a reduction based on metaphysical identifications. (Gozzano, 2003, p. 8).

Here Gozzano states that if a robust reductionism is what is argued for, not just of epistemological but of ontological kind, what is necessary is identity for properties independent of from our laws of nature because of their contingent character (ibid.). In this, Gozzano states that Kim has, at most, shown that this nomological identification allows for epistemological reduction. If this statement holds, Gozzano argues, Kim has not addressed the relevant discussion on, whether the second-order mental properties are amenable to the physical and the problem of mental causation; thus, the problems of robust reductionism remain present.

As an argument for the causal efficacy of mental properties, Gozzano raises an argument with an example of a water molecule:

> Consider now the property of being an ice cube. This is a *second order micro-based property* because it is the property of being an aggregate of H_2O molecules satisfying the further condition of being in a certain energetic state. As such, an ice cube has different causal powers from a water drop or a steam flow. The micro constituents are the same, what changes is their relation. Hence, second order properties have causal powers given the particular relations that hold among their constituents. (Gozzano, 2003, p. 11)

According to this argument, mental states, though here affiliated with physical states, are not in danger of losing their causal efficacy. The heart of the argument lies at the relation between the constituents of the phenomenon to occur. Kim, however, would not think that this argument of second-order properties would transfer to mental states as "[…] *the causal role of a mental property had by me is threatened with preemption by another property, a neural property, also had by me*" (Kim, 2000, p. 117). Kim's idea is that specific mereological relations can be led back to the constituent base properties and that these are the only properties that determine the phenomenon's causal powers. Gozzano would counter this as the causal powers of basic physical properties are

determined not only by its constituents but also by its relations, and Gozzano states that "[…] *there is no reason for not applying the same reasoning to mental properties*" (Gozzano, 2003, p. 11).
To sum up, Gozzano argues that Kim's program has failed in that epistemological solutions to the functionalization of second-order mental properties does not address the real metaphysical, or ontological, problem. Gozzano points towards the two things that realize a physical property and transfer to second-order mental properties; the constituents of the property and the relations they hold, thereby arguing that Kim's program is invalid in disclaiming the causal powers of the mental.

5.2 The situated view on the mind

As this discussion has been brought forth, certain inconsistencies have been pointed out on the arguments for the mind-body problem, mental causation, and reductionism by Jaegwon Kim that omit the possibility of emergent phenomena. In the following section, arguments from situated cognition will be brought forth that point towards this not being the case for the description of situated mental phenomena; that these are not merely amenable to the kind of functionalization required for reductive explanation of mental properties to their physical base properties.

The movement of situated cognition insists that an agent and its activities are deeply embedded in the dynamic interactions with its body and its environment (Bechtel, 2009, p. 155). Debaters from this extended-mind perspective thus maintain that cognitive processes such as perceiving, reasoning and problem solving do not solely take place internally within the agent, but that they also extend into the environment that surrounds them (ibid.). In this light, the environment also becomes part of the mind and is not a closed system, but an open one. William Bechtel argues that in order for situated cognition to strive, it is not necessary to deny the mind-body as the locus of control but that the agency of the mind is not alone fixated internally (ibid.). There is a need for agency, when an agent is so intertwined with its environment that the responsible system for a phenomenon to occur incorporates more agents and their environments, and that these are not mere psychological or behavioral phenomena, but inherently social ones. Although this is a rather radical statement, Bechtel still contends that for most explanatory challenges addressed by cognitive neuroscience, the mind-body is the correct locus of control, even for processes that critically depend on the ways that agents are situated in an environment (ibid., p. 156).

In order to join the neuroscientific project of identifying mechanisms in the brain with situated cognition, a clear definition of the term 'mechanism' is necessary. Here, Bechtel defines a mechanism as a bounded system selectively open to its environment, which it depends on in giving rise to certain phenomena, whereas biological mechanisms are self-maintaining organisms that are dependent on their environments and at the same time in certain situations, autonomous from them (ibid.). In extension of this, Bechtel notes that a core feature of understanding a mechanism is the idea that in consists of parts that perform different operations, and that mechanisms exist in nature, whereas mechanistic explanation involves presenting an account of the mechanism responsible for a given phenomenon to occur. Thereby, it seems that although Bechtel and Kim disagree on fundamental concerns of the mind-body debate, they agree on the distinction between explaining a mechanism that describes the determination of a relationship, versus an explanation of itself (Bechtel, 2009, p. 160; Kim, 2000, pp. 18-27). However, the extent of disagreement is much larger on more fundamental premises. For example, in regard to reduction, Bechtel states the profound difficulties of identifying the reductive links in a mechanism in order to decompose it, and further argues with an example against a domain-specific approach to modules in the brain:

> The fact that the operations that parts of a mechanism perform are different from the phenomenon exhibited by the whole mechanism and individually do not realize the phenomenon makes the working parts of a mechanism different from domain-specific modules. (Bechtel, 2009, p. 160)

This exemplification can be seen as an argument for emergent phenomena in that parts of a mechanism do not realize the phenomenon in itself, thereby differentiating themselves from functional reductive explanation. On the other hand, it can be argued that this example does not entail any external factors but only works as an argument against modularity, remaining an argument resting on a closed system, and therefore still being amenable to the kind of functionalization required for reductive explanation. But what Bechtel actually intends with this is that it is not possible to think in terms of dichotomy between modular and holistic accounts of the mind, and that differentiating between parts and wholes is not fruitful. This is so, as the operations of the component parts of a mechanism are determined not alone by their internal states (and thus the ones that would be functionally reducible) but also by the external factors affecting the mechanism as a result of the operation of these other components (ibid., p. 161).

In a way this addresses the previous discussion of Kim's philosophical concepts of reductionism and highlight the necessary two causal roles in focus; that of both the brain and the environment.

To elaborate, certain external, or societal, factors and tendencies in the environment are here said to exert influence on the parts, perhaps neurochemical, of the mechanism, perhaps of addiction, both of which are in part responsible for the resulting mechanism that is said to be both internally and externally invoked. Here, 'other components' could be seen as multiple aspects of cognitive functioning such as the neuroscientific aspects of addiction, which include more theoretical aspects of brain functioning. Herbert Simon articulated the idea that natural systems would most likely be 'nearly decomposable', meaning that hierarchical systems can 'nearly' be fully reduced, and that this characteristic is necessary to accept in order to understand them:

> […] If there are important systems in the world that are complex without being hierarchic, they may to a considerable extent escape our observation and understanding. Analysis of their behavior would involve such detailed knowledge and calculation of the interactions of their elementary parts that it would be beyond our capacities of memory and computation. (Simon, 1996, p. 207)

Here, here is seen a clear contrast between modular accounts of cognitive neuroscience and the view presented above. Consider an example of an autonomous system and how this is operating in its environment; taking in nutrients from it and putting waste products out into it. A cell in the system might excrete chemical substances into its environment that are advantageous to the organism. This way, a cell might grow independent from having to find nutrients in its environment and to remove its waste while still being able to move to secure nutrients and avoid waste products (Bechtel, 2009, p. 164). Hereby, the changes to the environment outside the organism is caused by the operations performed by the organism itself. The fact that biological systems are autonomous in this sense shows that their autonomy depends on the organism's own organized component mechanisms that perform operations to maintain themselves.

In more complex systems, however, the organism's operations reach the environment in a deeper sense, although these are in systemic closure, according to Bechtel (ibid.). Understanding how this occurs is of primary interest to the thesis and may justify these processes as being independent from and irreducible to the physical domain. This points towards a distinction between simple living organisms such as bacterial cells that only have a membrane surrounding their whole cytoplasm and more complex systems. As these more complex systems are taken into consideration, another problem arises; that of different mechanisms interfering with each other (ibid.). As such, the explanation of mechanisms does not have to involve a dichotomous choice of either a strongly modular approach to cognition or an extreme holistic approach to cognition as Kim implies with his lack of belief in so-called 'middle-of-the-road' positions such as property dualism, anomalous

monism and non-reductive physicalism (Kim, 2000, p. 120). Oppositional to this, such ‘middle-of-the-road’ positions will allow the identification of systems on a continuum between the extremes that can open up the vault for a discussion of the existence of situated cognitive mechanisms.

In discussing the idea that different mechanisms can interfere with each other in complex systems, and how this may imply the existence of emergent phenomena, it is necessary to argue that these single basic mechanisms can interfere with one another across different levels of description. For example, there exist an extensive literature on neurophysiological evidence of long term potentiation (LTP) and long term depression (LTD) of neural firings as conditioning for learning to take place by strengthening neural pathways. This, when taking into account larger components of the organism, alters the brain over time, and can alter certain regions of the brain that process information contingent for certain brain regions to change. This can change brain regions after repeated learning over time such as seen in Part A of the thesis, in which the scientific study shows certain volumetric brain increases such as that in the ventral striatum. This increase is attributed to an isolation of the effects of excess consumption of and activities with a certain behavior; CSB. Now reaching an even more abstract level of description, this change is correlated with the effect of behavioral output. In diagnostic interviews, when CSB subjects are asked to account for the reason for their behaviors, unanimously, subjects attribute their behaviors as being conditioned by society’s acceptance of and availability of sexually explicit material. Thus, in such a most complex system as human consists of with their brains, the system seems open to changes from society from effects that cannot be attributed merely to the sum of its parts, and must be said to exist in an open system of vastly interchanging dynamics of groups of individuals.

This example, which implies both theoretical and empirical evidence, elaborates the distinction between a closed versus an open system, and when such a mechanism can be said to be embedded in one or the other. As already described, living organisms are distinct from their environments as systems that construct and reconstruct themselves (Bechtel, 2009, p. 164). But to understand how this is done, a main enterprise of science is to differentiate an organism or an agent from its environment or society, while still recognizing that it engages in external activities. Here, a parallel can be drawn to looking at different correlations between dependent and independent variables, which is also the case in Part A of the thesis; that acknowledging an agent's engagement in its environment does have causal influences, which are teased out by operationalizing experimental

setups able to capture this differentiation. This is done in terms of correlating a behavior imbedded in an agent's nervous system as a consequence of a behavior affected by society, according to patients' reports.

In these complex systems, such as the ones humans are regarded as, the dependencies of the environment are thus important in order to function as opposed to simple organisms dependent on their environments. Agents must make complex decisions in today's society, which require them to perform a large array of different behaviors and to make numerous choices, which affect and in time alter agents. This is exemplified through CSB subjects engaging in their environments and are unable to stay unaffected from this, which is perceived through their subjective reports. This fits with Bechtel's framework of cognitive agents having interests in certain behaviors and in recruiting components of their environments to enable certain experiences that depend on such behavior.

Bechtel stresses that researchers need to move to a more inclusive system for explaining phenomena involving human behavior (ibid., p. 167). Here, a framework has been set in which individual agents are perceived to be the locus of control for their own actions, although there is a reason for shifting the locus of control to the effects of their environments; it is this very social domain that is maintained by the operations performed by agents. Still in this continuum, situated cognition refers to the activities of agents in their environment and thus, the locus of control stays with the agent. Thereby, the boundary between an agent and its environment as well as between the different components and subcomponents of the agent seem somewhat permeable. So when a system is identified as the locus of control for a particular function, it is not necessarily true to attribute full responsibility to that system, according to Bechtel (ibid.). This is so, as its functioning may be dependent on the external, or the environment, where agents exert influence. To draw another parallel to Part A of the thesis, the ventral striatum is not perceived to be fully responsible and as the locus of control for addiction. In spite of the fact that this brain region has evolved to respond to the expectation and experience of reward, it is dependent on the choices that an agent makes in terms of environmental exposure to reward-seeking behaviors. And when the environment, to which the system is bound, is filled with reward-inducing cues, the whole system, or agent, becomes more susceptible to this detrimental change, fully intertwined between the agent's nervous system and its environment. This way, and through an application of Bechtel's account, it should be more likely to demarcate the effects of the agent itself, through investigating its situated nature in the environment.

The neuroscientific approach taken in Part A of the thesis, having applied an appropriate experimental design in order to measure the effects of CSB, can in itself be argued to be susceptible to such demarcation, which has been the premise for this section of the thesis.

On behalf of the discussion of agent and brain as a whole system, open to influence from and dependent on the environment, understanding how an agent and its cognitive mechanisms are functioning and situated in its environment are relevant questions for the complementation of Kim's framework. These dependencies on the brain, in the environment, are crucial for creating the addiction model and for the understanding of higher cognitive tasks as the next chapter will show.

5.3 Conclusions for chapter five and addiction model perspectives

In order to elaborate on the addiction model, the end of chapter four will be briefly revisited. Here, it was concluded that given the supervenience argument, it makes no sense to claim that societal and neuroscientific factors of addiction should be considered as two causal relationships unfolding separately but rather as being intertwined. In this chapter, the previous discussion on reduction has now been extended to a discussion on causality, which has argued for the importance of including perspectives from situated cognition in order to explain the phenomenon of addiction. The next step in creating the addiction model is to delineate this relationship between these different explanations.

The present chapter has presented an anti-reductionist position that has complimented and contradicted Kim's program in chapter four. Here, when providing such an anti-reductionist framework as an explanation, it must be viable to speak of both mental and physical properties, as these were earlier concluded to co-exist. Conversely, if a reductionist program would have been proposed, it would not had been necessary to attribute significance to the mental, as the physical would have been sufficient as the proper cause.

On behalf of these conclusions, it seems difficult to claim identity between the mental and the physical, which is what is required for Kim's reductionist program. Thus, we must seek to understand the relation between the mental and the physical. Here, as has been argued, reduction and emergentism are possible positions, among many others. After an anti-reductionist position was taken in chapter four towards creating the addiction model, it makes sense to look at these levels of

description separately. The following chapter will thus focus on both mental and physical aspects of addiction, functioning as the final step in integrating the addiction model.

In delineating the relationship between the mental and the physical, an example will be provided. Given the supervenience argument as part of the addiction model, it is not contradictory when CSB subjects 'psychologically' attribute society as being the primary reason for their addictions, and that it is possible to measure 'physically' components of this addiction at the same time. In fact, it seems to be in accordance with each other, and can be argued to make excellent sense in that patients' qualitative reports correlate with the findings in Part A of the thesis. There somehow appears to be a correlation between the properties of what is mental and what is measured physically.
At this point, the ongoing discussion towards creating the addiction model must be capable of granting society's way of altering human biology. So on behalf of the irreducibility of qualia, when CSB subjects report society as responsible for their addictions, this must highlight a fraction of the ontological explanation of addiction. In line with this, what the above example illustrates is not a conflicting relation but rather an integrated one, showing how subjects' reports can hold elements of ontological truth although too narrow to comprise the addiction model in isolation.

The final step in creating the addiction model will thus be to take on a discussion on the methodological problem which relates to, how it is methodologically possible to understand the content of the mental and how it can generate the physical. Treating this problem will be approached by providing a list of both mental and physical properties associated to addiction. In spite of the fact that the relationship between these two lists is unknown, on behalf of the conclusions so far, it is considered meaningful to utilize these lists to look for corresponding tendencies. This integration may be helpful in providing guidelines for future research, both empirically and theoretically, in contributing to the research literature and to make an extension to the scientific study in Part A of the thesis. This should contextualize the thesis to understand more deeply the influence of different factors within addiction and the mind-body relationship.

In this way, the addiction model will be applied on both a general and a specific premise; generally the model will apply a perspective that treat a central problem that have existed throughout the history of psychology in the form of the mind-body problem, and specifically the model will apply to the scientific study in Part A of the thesis.

6. Methodological considerations – the addiction model

Summing up the conclusions from chapter four and five, the thesis has moved in the direction of creating a model of addiction on behalf of these chapters' focus on an ontological problem related to reductionism and causality. Part B of the thesis will now change its course towards the second theoretical problem; a methodological approach to explanation of mental and physical phenomena. This will be done by including both qualitative reports from clinical subjects and neuroscientific evidence related to the scientific study in Part A of the thesis. This will be discussed on behalf of a rationale for listing the factors thought to be of significance in explaining the phenomenon of addiction. As the earlier perspectives on the addiction model have concluded, the importance of both mental and physical properties are recognized as being distinct phenomena and hence, the addiction model will further develop from this anti-reductionist position.

6.1 Qualitative reports related to the addiction model

On behalf of recognizing both mental and physical properties as being distinct properties, in the following section, examples of clinical subjects reporting society's effects on their addictions will be presented as a means of purposefully grasping the mental or psychological component of addiction, which will subsequently be compared with a corresponding list for the physical or neural component, in order to correlate the two.

The reason for assembling the addiction model through the listing of mental and physical properties and states also comes from a lack of knowledge about, what mental states represent and how they are measured. As an example, an argument will be presented in the form of, how neural states, when measured, cannot be taken for granted as pure derivations of physical states. Rather, these must be seen as dependent on the conditions set for such a measure. This is so, as it is only possible to investigate neural states, as done in Part A of the thesis, through a sort of mapping of the mental state unto the neural state. This will be exemplified in this section, where the proposed mental properties will be listed.

In a recent scientific study in CSB, subjects reported that as a result of excessive use of sexually explicit material, they had lost jobs due to use at work, damaged intimate relationships or negatively

influenced other social activities, experienced diminished libido or erectile function specifically in physical relationships with women but not in relationship to sexually explicit material, used escorts excessively and experienced suicidal ideation. Furthermore, ten out of 19 subjects in the study either had or were in counselling for their behaviors (Voon et al., 2014, p. 3f). This tendency, when compared with the diagnostic screening interviews in the thesis' study in Part A of the thesis, is converging. Here, when the subjects who participated in the present study were interviewed before testing, unanimously CSB subjects reported the profound influence of the exposure on the Internet and in the media on their behaviors.

As will now be exemplified, these subjects attribute their behaviors to a shifting societal tendency. The qualitative reports are from declared addicts, although not officially diagnosed CSB subjects. Common for the quotes are the ties to society's and technology's attributed effects on their reports:

> With the magazines, porn use was a few times a week and I could basically regulate it 'cause it wasn't really that 'special'. But when I entered the murky world of Internet porn, my brain had found something it just wanted more and more of. I was out of control in less than 6 months. Years of mags: no problems. A few months of online porn: hooked. (Wilson, 2014, p. 24)

Then in 2006, when the Internet's availability of sexually explicit material escalated to the emergence of the so-called 'tube sites', several declared addicts of this material reported the hallmark's influence as substantial to their addictions and behaviors:

> When I got Internet back in my late teens I found many YouTube-like porn sites that categorized content by fetishes. At first my tastes were those of a normal teenage boy, but over the years my tastes shifted into aggressive content. [...] Within a year I had acquired many new fetishes, each changing within a shorter time frame than the one before it. I'm experimenting with quitting because my tastes are now making me really uncomfortable. They conflict with my sexuality. (Wilson, 2014, p. 55)

And:

> Tube sites, especially the big ones, are the crack cocaine of Internet pornography. There is so much of it, and so much new content every day, every hour, every 10 minutes that I was always able to find constant new stimulation. (Wilson, 2014, p. 26)

The two above statements are examples of the technological advance in the form of high-speed Internet that is transmitted to everyone through the Internet. A mechanism that clearly is attributed significance and has affected behavior for these persons. And the technological traces in this goes even further, as today's smartphones are capable of channelling such connections as well:

> Now with high-speed, even to smartphones, it has made me continuously watch more and more and at higher resolution. It sometimes becomes a whole day affair looking for the perfect one […]. It never, ever satisfies. 'Need more' the brain always says…such a lie. (Wilson, 2014, p. 26)

Because of the structure of these websites and the fast technological advances taking place, visitors are able to constantly seek out new material. As we shall see in the next section from a neuroscientific perspective, this can override the brain's natural satiation mechanisms. What these reports underscore is a societal shift, which subjects report being amenable to change from; one that is clearly attributed as being facilitating for their addictions and behaviors.

Another significant perspective is that what is measured physically seems to be dependent on the mental. This is so as qualitative judgments are made when an investigator is designing experiments, which in turn has a profound influence on how the physical is measured. This can be seen in terms of, how researchers and therapists set diagnostic criteria, which is characterized by a combination of patients' symptoms and their own criteria for diagnosis. Similarly, and as seen in Part A of the thesis, it is also the qualitative judgments of researchers that determine, which patients end up in the MRI scanners, depending on how stringent or liberal these criteria are set. This way, when correlating a behavior such as CSB with its neural states and properties, as done in Part A of the thesis, it is important to note how mental components can be seen as dispositional to the physical data that neuroimaging allows to meaure. Resting on this argument, it seems impossible to conduct neuroscientific research without taking seriously the subjective reports from patients. If the qualitative method of classifying diagnistic criteria is left out, what ends up as neuroscientific data and hence a physical measure, is confounded by unsystematic noise through lack of experimental control. This way, physical or neural analyses and measures can be said to be dependent on mental properties.

In terms of methodology from this perspective, this argument goes well with the methods section in Part A of the thesis. Here, it is presented how the neural data must be validated on behalf of having set clear diagnostic criteria in order to avoid unsystematic variation across participants. This applies to many lines of neuroscientific research, in that what is measured neurally or physically is often correlated with behavior; a form of behavior that has been assessed on behalf of researchers' own qualitative assessments. Thus, one of the fundamental methods in neuroscientific research can be said to be qualitative and mentally derived, and thus conditional for what is physically measured.

These qualitative reports, along with taking into account the predispositional nature of the mental for the physical data output, are intended to be set aside with mental properties that clearly seem to separate themselves from physical properties. Here, when we are to understand addiction, qualitative reports are granted significance through the supervenience argument and the irreducibility of qualia. The reason for including these is that the reports serve as a step in integrating the two lists that will comprise the addiction model. The next step will present the other list of neuroscientific evidence that is relevant for the creation of the addiction model, which will serve as the final step before integrating the model.

6.2 Neuroscientific evidence related to the addiction model

In the following sections, a central core of neuroscientific evidence related to addiction will be presented to show what is conditioning for addiction. This will be done in order to list physical or neural aspects of addiction, which are argued to be separate from mental or psychological ones.

6.2.1 Neuroplasticity and addiction

Neuroplasticity is an active phenomenon constantly occurring in the brain, which enables neuronal growth and learning. Although fundamental for beneficial processes such as these, not all aspects of neuroplasticity are beneficial as addiction is a phenomenon that usually begins because with powerful reinforcement from a stimulus, be it drugs or behaviors (Breedlove, 2013, p. 118f). Many addictive drugs cause the release of dopamine (DA) in the ventral striatum (VS), as is the case with natural rewards such as food or sex (D'Ardenne et al., 2008, p. 1264). In addition, DA released from axons originating from the ventral tegmental area (VTA), part of the mesolimbocortical dopaminergic pathway, is widely implicated in sexual reward. And as the dopaminergic pathway from the VTA to VS acts as a reward system, the addictive power of these stimuli is believed to arise out of stimulation of this pathway (Doidge, 2007, p. 199f). So when an effect, be it a drug or a specific behavior, takes over this system, subjects begin to associate the drug or behavior with reward and thus to seek out more of that experience, which can lead to addictive and compulsive behaviors.

In integrating this wanting of the stimulus, cognitive aspects of addiction are mediated by glutamatergic inputs from the PFC that, among many things, integrate aspects of memory, attention and self-control and regulate the functioning of the dopaminergic system (Breedlove, 2013, p. 119). Seeking to explain the binging mechanisms of CSB subjects, it has been discovered that accumulation of a specific molecular switch called Delta FosB is highly correlated with DA release in the VS (Pitchers et al., 2010, p. 838). It has since been hypothesized that increased accumulation of Delta FosB in the VS decreases specific brain pathways going from the VS to the PFC. Thus potentially, Delta FosB can be a key variable in accounting for subject reports of desensitization based on animal research models (Fiorino et al., 1997, p. 4849).

Perhaps most importantly, these regions are also involved in higher order cognitive and motivational functions, such as the ability to modulate the salience of a reinforcer as a function of context and expectation, and the ability to control and inhibit prepotent responses (Goldstein & Volkow, 2002, p. 1642). Such results points towards addiction involving cortically regulated cognitive and emotional processes, which result in the overvaluing of drug reinforcers and promotes deficits in inhibitory control.

Changes in the held views on addiction such as these expand, as knowledge becomes greater. Recent evidence suggests that there are shared behavioral mechanisms for compulsivity and impulsivity, as both promote disinhibition as well as dysfunctional inhibition from thoughts and behaviors. This is presumed to result either from failures in ‘top-down’ cognitive control of fronto-striatal circuits, or alternatively from overactivity within striatal circuits of the brain (Fineberg et al., 2013, p. 71, 75; Stern et al., 1995, p. 265). Furthermore, the developing adolescent brain is at higher risk of developing an addiction compared to adults’ as the synapse rearrangement in the PFC continues into the early twenties, whereas limbic regions such as the VS are fully matured from early adolescence (Breedlove, 2013, p. 199). From a clinical perspective, this means that the CSB subjects of the future may become addicted at an earlier stage than seen now, and between full maturation of the VS and PFC.

A direct consequence of the neuroplastic potential of the brain is seen in Part A of the thesis, where exactly the VS is structurally enlarged as a consequence of CSB, converging with much evidence from research on reward processing as shown in the study. These findings were also converging

with a previous study in CSB, where subjects exhibited hyperactivation of the VS. This is yet again convergent in the sense that extensive neural activity associated with certain behavior can enlarge associated brain structures over time (Granert et al. 2011). This means that new synapses can form as well as more frequently used pathways can take over neuronal clusters formerly occupied by less active ones. These changes in the CSB subjects' brains are clear examples of neuroplasticity, which causes physiological brain changes. On a physiological level, these conditioners for addiction can result from increases in neurotransmission going from presynaptic neurons or from increased receptors in the postsynaptic neurons (Breedlove, 2013, p. 542).

6.2.2 Competing systems in eliciting behavior

A central part of what drives addiction in the brain is comprised of behavioral traits that are each linked to specific systems of brain functioning. The behavioral traits most often used are impulsivity and compulsivity (Fineberg et al., 2013, p. 71f). Both of these concepts comprise disruption of a wider range of neural processes, such as attention, perception, and coordination of motor- or cognitive responses (ibid.). These processes are thought to be supported by separate but communicating 'impulsive' and 'compulsive' cortico-striatal neurocircuitry. Here, each of the circuits have been found to be modulated by different neurotransmitters (Brewer et al., 2008, p. 998; Robbins, 2007, p. 917). Current neuroanatomical models have found evidence that at least two nodes in the striatum, an impulsive and a compulsive one, drive these behaviors, while two corresponding nodes in the PFC restrain them. Thus, the impulsive circuit may comprise a striatal component of the ventral striatum and the nucleus accumbens that drives the impulsive behaviors, whereas a prefrontal component of the anterior cingulate and the ventromedial prefrontal cortex exerts inhibition and control. In the same way, merely in the compulsive circuit, another striatal component consisting of the caudate nucleus and putamen is thought to drive compulsive behaviors, and a prefrontal component consisting of the orbitofrontal cortex may exert inhibitory control (Fineberg et al., 2013, p. 71f). In this way, there can be said to exist somehow competing systems in correspondence with different behavioral traits in the brain, with certain cortico-striatal components being facilitatory and others being inhibitory in the kind of impulsive and compulsive behaviors that lead to addiction.

The roles of these regions applied on a behavioral level means that hyperactivity in striatal components of the brain may result in increased automatic tendencies for impulsive and compulsive

behaviors, depending on which subcomponents of this region is affected, whereas the same is the case for hypoactivity in subcomponents of the PFC (ibid.). For example, research in OCD shows fronto-striatal dysfunction during planning, which manifests as hyperactivation in resting state fMRI but hypoactivation of the DLPFC and the OFC during executive functioning (van den Heuvel et al., 2005, p. 301). This example states the understanding of addictive behaviors as something that is linked through assessing neural correlates of elicited behavior, here in the case of cognitive inflexibility.

6.2.3 Dissociating 'wanting' and 'liking'

Over the past two decades it has been increasingly recognized that drugs change the brains of addicts, also to a greater extent that what earlier had been linked to the behavioral traits of tolerance and withdrawal. In 1993, a study was published on the incentive sensitization theory, stating that the most important psychological changes to an addiction is a sensitization or hypersensitivity to the incentive motivational effects of drugs and drug-associated stimuli (Robinson & Berridge, 1993, p. 247). In this, "[…] *incentive sensitization produces a bias of attentional processing towards drug-associated stimuli and pathological motivation for drugs (compulsive 'wanting')*" (ibid.).

Similarly, different models have been presented to explain the phenomenon of addiction, one of which is that 'wanting' becomes dissociated with 'liking' as the process of addiction begins. Through this dissociation, the sensitization of dopamine systems is conditioned by associative learning, which causes excessive incentive salience to be attributed to stimuli associated with a drug or the effect of certain stimuli (ibid.). In this, it is specifically the sensitization of incentive salience that changes normal 'wanting' into excessive craving. It is also believed that the sensitization of the neural systems responsible for 'wanting' can take place independently from neural changes in systems responsible for 'liking', and from the systems that facilitate withdrawal (ibid.). This way, the sensitization of 'wanting' can produce addictive behaviors such as compulsive drug seeking and drug taking, and this in spite of building tolerance to the drug, which diminishes expectation and experience of reward (ibid.).

Consistent with such a theory, a recent study has shown that, relative to healthy volunteers, CSB subjects had greater 'desire' but similar 'liking' scores in response to sexually explicit material presented in the study (Voon et al, 2014, p. 1). The results on the dissociation between 'wanting'

and ‘liking’ from this study are thus consistent with the incentive sensitization theory, which had originally been developed for substance abuse and not for behavioral addictions such as CSB. This meant that there was observed aberrant and deviant measures on ‘wanting’ in CSB subjects, whereas measures on ‘liking’ were similar to the group of healthy volunteers. Furthermore, the exposure to sexually explicit material was stronger with associated activation of the dorsal anterior cingulate, ventral striatum and amygdala in CSB compared to non-CSB subjects, regions previously implicated in drug-cue reactivity studies (ibid.). Finally, the functional connectivity of this network was associated with ‘wanting’, and not with ‘liking’ to a greater extent in CSB subjects compared with healthy controls.

However, the incentive sensitization theory does not take into account the discussion on reductionism and causality related to the metaphysical aspects of the mind-body problem, which the present thesis has sought to treat. Rather, such a theory does not seek to join the traits of ‘wanting’ and ‘liking’ with mental aspects of addiction. As a critical note, taking this discussion into account, it seems problematic to explain the distinction between ‘wanting’ and ‘liking’ without reference to mental differences. This is so, as the concepts by definition are two different *mental* states. Taking into account the literature on ‘wanting’ and ‘liking’, this serves as an example of, how mentally derived phenomena can be intertwined in neuroscientific research, although not treated systematically or even as the mental phenomena that they are.

Thus, this story is motivating for the present discussion on methodology, as this example highlights a problem that have existed throughout the history of psychology; the mind-body problem. Therefore, in the final section, this will be taken into account in assembling the addiction model, which concludes the findings of the thesis.

7. Conclusion – presenting the addiction model

In order to conclude the thesis findings and present the addiction model, it must be noted that the addiction model will function as an integrative way of treating a basic problem in psychology in the form of the mind-body problem, and relating it to an applied domain in cognitive neuroscience in the form of creating future directions for experimental operationalizations of neuroscientific studies on addiction. The process of creating the addiction model has been established through a theoretical problem that arose out of Part A of the thesis, which is partly ontological, treated in chapters four and five, and partly metodological, treated in chapter six.

The conclusions from the neuroscientific study in Part A of the thesis left unaddressed, how we are to understand the relationship between the two sets of qualitative and quantitative data that are correlated, which shed light on the ontological problem. This problem relates to understanding the relation between the mental and the physical, and in which discussions from chapter four and five focused on the metaphysics of the mind, reductionism, causality, and the situated view on the mind. In light of the methodological problem, it stood uncertain to what degree the measures of addiction implemented in Part A of the thesis were representative of addiction as it plays out in the real world. This shed light on a methodological problem of measurement of the mental and the physical, and thus the method at which the structural brain correlates of CSB have been assessed. This raised a rationale for compiling two lists of mental and physical properties, which was done on behalf of the partial conclusions from chapter four and five. The discussion on, what the structural brain correlates of CSB represent highlighted, how this is decided through the ways that researchers design experiments, screen potential subjects, et cetera. When, for example, a structural MRI picture is inspected, what this picture represents is a product of researchers' intentions and criteria set for their subjects' participation in a given study. This was discussed in order to problematize how to ontologically grasp the state of addiction as it is.

The partial conclusions stated after treating the ontological and methodological problems have served as steps towards presenting the addiction model. On the basis of these conclusions, the addiction model should be able to highlight directions for addiction research, and to predict and further delineate aspects of addiction. In this regard, treating the ontological problem should make way of operationalizing experiments, which take into account the methodological problem.

As the addiction model have sought to consider both the mind-body problem and neuroscientific evidence, several steps are needed in order to present it. Acknowledging the ontological problem, which is related to the type of explanation that can be used to understand the relation between the mental and the physical, led to a discussion on the metaphysics of the mind, including reductionism and causality. The partial conclusions on behalf of the anti-reductionist position taken in chapter four and five of the thesis underscores the importance of the distintive character of both mental and physical properties that each have been granted significance. And given the supervenience argument, it was proposed that there exists a causal relationship between *M* and *P*, or the mental and the physical. Furthermore, through the discussion of the methodological problem, which is related to the methods and measures applied to measure mental and physical properties of addiction, the distinctive character of mental and physical properties was presented. Thus, the methodological discussion has provided each of the adapted lists representing mental and physical properties of addiction, which sought to highlight the distinctive aspects of different properties of addiction.

So in order to create the addiction model that joins the discussions throughout the thesis, in this section the components from each of the two lists will be correlated to see, which components from the list representing mental properties, in the form of addicts' qualitative reports of their behaviors, correlate with components of the list representing physical properties, in the form of neuroscientific evidence related to addiction. Hence, in integrating the addiction model, an attempt will be made to grasp the actually existing causal relationship between *M* and *P* through this correlation of the two lists compiled on behalf of the arguments from the ontological and the methodological problem, which Part A of the thesis left unaddressed. Finally, the model will state its purpose.

To correlate the lists, from the earlier presented unanimous statements from addicts of sexually explicit material, it stood clear that the subjects' addictions were attributed to an effect 'external to' or 'outside of' themselves. This way, addicts described their reality as living in an environment constantly able to reinforce their addictive behaviors. A brief analogy to a substance abuser would seem terrifying in terms of an environment constantly able to reinforce the drug dependence, and from a psychological point of view, the consequence of being in such an environment and helping the substance abuser, would be to physically remove the person from the environment holding such strong enablers. However, this is not the case with the reported subjects, as their addictions are legal, and as in Western society, frequent use of this material is considered normal and unharmning.

However, the neuroscientific evidence related to addiction presented earlier showed, how this was not the case. For example, it was presented, how incentive sensitization can produce attentional biases towards compulsive wanting of a reinforcer. Also, it has been recognized that a continuous state of addiction changes brain functioning and structure, and this to a greater extent than previously believed. For example, a clear consequence of the neuroplastic potential of the brain was seen in Part A of the thesis, where the ventral striatum was structurally enlarged as a consequence of CSB. Functionally this makes sense, as addicts spend excessive amounts of time seeking to gain pleasure from their behaviors. On the basis of the neuroscientific fact that extensive neural activity associated with CSB can enlarge associated brain structures such as the ventral striatum, the addiction model seeks to correlate this evidence with these subject' reports.

The correlation between mental and physical properties can be seen in several aspects. First of all through reports from these subjects, which are granted distinct significance as representing mental properties. This has been done on a basis of the conclusions from chapter four and five of the thesis; partly in relation to the supervenience argument discussed in chapter four, and partly because of the anti-reductionist position proposed as a consequence of the situated view on the mind discussed in chapter five. With significance granted to these qualitative statements argued to represent 'qualia', and thus with the mental as being distinct form the physical, it is concluded that these statements hold a truth, which neuroscientific and physical evidence related to addiction in isolation does not.

Through this line of thought, what these statements represent highly correlates with the second list of neuroscientific evidence related to addiction, as subjects report being in a state of *addiction*. This way, the list representing physical properties can explain their reported addictions through its listed conditions. However, the list representing mental properties cannot be explained by or correlated with the list representing physical properties with regard to, what their addictions are *attributed* to, this being the environment's influence on their behaviors. In this specific regard, the two lists seem to lack correlation. This is so, as the physical list is not engaged with providing the explanatory values of addiction, but merely neuroscientific facts related to addiction. On the contrary, the addiction model is engaged with exactly this explanatory value of addiction.

The model, supposed to explain the relationship between mental and physical aspects of addiction, can be said to contain three steps; the first of which is to collect the two lists of distinct mental and physical properties, each having been granted significance through the supervenience argument;

second, to correlate the lists; and third, to provide the explanatory value of the found correlation, which excludes the possibility of reductionism, based on the proposed anti-reductionist position.

On a basis of this delination, the purpose of the addiction model is to develop methods to handle the problem of having two sources of evidence that are to be correlated. On the basis of the two lists having been correlated, the contribution of the addiction model is both to handle the necessity of such a correlation, but also to ensure that these lists remain separated. Thus, the model has the purpose of moving from correlation of mental and physical properties of addiction, and towards explaining their relation. This is to be done partly through correlating the lists methodologically, and partly through raising the ontological question of, what the relation is between these lists.

The first two steps of compiling and correlating the lists of mental and physical properties are related to existing research practice. However, the addiction model points towards the necessity of a third step on the basis of the preceding chapters, which relates to the explanation of the found correlation, without reductionism. However, the model is not able to explain this third step entirely. Rather, it is able to provide a foundation for this necessary step in order for explanation to occur. As such, the addiction model rests on and points towards this step. And if the two lists representing mental and physical properties are taken as scientific aspects of the existing relationship between the mental and the physical, then both are necessary in providing an explanatory model of addiction.

This way, the addiction model seeks to utilize both neuroscientific mechanisms and their relation to qualitative statements. The consequence of this argument is that such an explanatory model grants the validation of both qualitative and quantitative data, and contains components from both mental and physical properties. Here, the ideal would be to discuss, how such an explanatory value is operationalized, in which additional work on the addiction model might be able to help bridge the gap between qualitative and quantitative research.

Thus, this Master’s thesis culminates in seeking to deliver an argument for, why present neuroscientific research practice holds problematic characteristics, and why there seems to exist a missing a set of explanatory data, which might enable the prediction of novel aspects of addiction, through experimental operationalization that grants mental properties their rightful significance.

8. References and curriculum

8.1 References and curriculum used in Part A of the Master's thesis

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