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INTRINSIC MOTIVATION AND ITS NEURAL CORRELATES

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Abstract

Why is motivation important? The answer is simple to most of us: it is what makes people push forward and act. Intrinsic motivation is the kind of motivation that arises from within a person, making her or him strive towards a goal for no other reward than the feeling it will bring. Additionally, this kind of motivation has shown correlations with enhanced learning, creativity, performance, optimal development, and well-being. While intrinsic motivation has long been a topic within the field of psychology, the neural correlates underlying it have only recently become of interest for researchers, and studies have shown some interesting but also contradictory findings. Therefore, the aim of this literature review thesis is to investigate the neural correlates of intrinsic motivation further. Firstly, a background review of motivation in general and intrinsic motivation in particular is presented, focusing on concepts such as the self-determination theory, flow, and cognitive evaluation theory. This is followed by a chapter on motivation- and intrinsic motivation from a neuroscientific perspective, concerning concepts such as the reward system, the undermining effect, and studies examining the neural correlates of intrinsic motivation. These studies show that there was activity in several different areas when participants were intrinsically motivated. However, a frequent pattern of activity in dopaminergic pathways involving the striatum and the prefrontal cortex (PFC) was detected in most studies, indicating the involvement of these areas in particular when a person is intrinsically motivated.

Keywords: Intrinsic motivation, self-determination theory, neuroscience, dopaminergic pathways

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1. Introduction

For a long time, scientists in areas such as decision-making and educational psychology have been interested in the nature of human motivation (Marsden, Ma, Deci, Ryan, & Chiu, 2015). The power of motivation is that it makes people act. It produces and makes people do what they do, which is why it is highly valued in most aspects in life (Ryan & Deci, 2000). A main motive for doing something can be the consequences or rewards it will bring. For instance, one may feel motivated to join a project, if one anticipates receiving money after joining it. However, another kind of motive for engaging in something may not be because of external rewards or consequences, but rather because of the satisfying experience it will bring to oneself internally. Here, a reason for participating in the project is because one believes that it will be interesting and bring feelings of enjoyment (Lee, Reeve, Xue, & Xiong, 2012).

A theory that has guided much research about motivation during recent decades is the Self-Determination Theory (SDT). This theory has focused mainly on the social-contextual conditions that enable or forestall the natural processes of self-motivation (Di Domenico & Ryan, 2017; Ryan & Deci, 2000). According to SDT, our actions can be driven by either extrinsic or intrinsic motivation. An example of extrinsic motivation is the case described above where one participates in the project in order to receive money. Hence, extrinsic motivation refers to having a goal or doing a task for the extrinsic rewards it will bring. In contrast, intrinsic motivation is described by the latter example where one participates in the project for the satisfying experience of it. Accordingly, intrinsic motivation refers to participating in an activity for no other reason or reward than the experience itself (Kaplan & Oudeyer, 2007; Ryan & Deci, 2000). According to SDT, the three psychological factors that affect motivation are competence, autonomy, and relatedness, where increases in these factors when engaging in an activity lead to intrinsic motivation and decreases lead to extrinsic motivation or amotivation (Hidi, 2016; Weinberg & Gould, 2014). People who are more intrinsically rather than extrinsically motivated have shown enhanced learning, creativity, performance, optimal development and well-being (Di Domenico & Ryan, 2017; Ryan & Deci, 2000). SDT has become a fundamental guideline for the study of intrinsic motivation (Di Domenico & Ryan, 2017), which is the main topic of this thesis.

Intrinsic motivation is the inherent tendency to explore, seek new experiences and challenges, to improve one's capacities, use creativity, and to learn. From birth, healthy children are curious, active and playful despite receiving no specific rewards from it. This spontaneous interest is crucial in social and cognitive development and it symbolizes a basic source of vitality and enjoyment throughout life. It refers to the authentic and self-authored striving towards a goal or a task, for the satisfying experience of it (Ryan & Deci, 2000) and for no other reward than the activity itself and the subjective positive effect it induces (Kaplan & Oudeyer, 2007). Although intrinsic motivation has been a topic within the field of motivation for a long time, it is only recently that its neural substrates have become of interest for researchers to examine (Ryan & Di Domenico, 2016). However, many studies have found different results in this new area making it still poorly understood in neuroscience research (Lee et al., 2012). A better understanding of the neural correlates of intrinsic motivation ought to provide a better understanding of the phenomenon as a whole (Di Domenico & Ryan, 2017) which may in turn help enhance performance in different settings such as educational performance (Miura, Tanabe, Sasaki, Harada, & Sadato, 2017).

1.1 Aim and Structure

The beneficial effects often seen from intrinsic motivation is what made me interested in the subject. The aim of this thesis is to investigate the neural correlates of intrinsic motivation. This will hopefully lead to a somewhat clearer picture of its neural correlates, or at least point out where we currently find ourselves in the manner. This will be realized by first, providing a theoretical background of motivation, presenting the SDT which has led most research about motivation during the past four decades (Di Domenico & Ryan, 2017). Further, a theoretical background of intrinsic motivation will be presented concerning concepts such as; flow, which is closely related to SDT's intrinsic motivation involving becoming totally absorbed in an activity and experience a non-self-conscious enjoyment from it (Di Domenico & Ryan, 2017); Loewenstein's information-gap concerning curiosity which he defines as "an intrinsically motivated desire for specific information" (Loewenstein, 1994, p. 87); plasticity found in the Big Five model of personality involving flexibility and exploration (DeYoung, 2010); and the Cognitive Evaluation Theory (CET), which is a sub-theory to SDT, involving factors that enhance intrinsic motivation such as being self-determined and to feel in control of one's actions, the optimal challenge of the action, the positive feedback from the action, and being task-involved rather than ego-involved (Mandigo & Holt, 2000). Second, a presentation of motivation and neuroscience will take place concerning the reward system, which is the brain structures in which reward processes take place (Hidi, 2016), and the undermining effect which is the phenomenon of the undermining effect that extrinsic rewards have on intrinsic motivation (Weinberg & Gould, 2014). This is followed by a presentation of studies from the past 10 years aiming to understand the neural correlates of intrinsic motivation. The findings from these studies are very different and some even contradictory. However, slight correlations can be seen where much intrinsic motivation in these studies activates dopaminergic pathways often involving prefrontal and even more so striatal regions. Further, a summary of the thesis will take place in the discussion, followed by comparisons and conclusions of the different neuroscientific studies discussing both coherent and contradictory results. Different literature of criticism towards various concepts from the thesis is presented.

Furthermore, to focus more specifically and investigate with greater depth the phenomenon of intrinsic motivation, extrinsic motivation is not considered in greater detail in this thesis. However, I do emphasize that comparisons between the two phenomena would be interesting to examine, especially from a neuroscientific perspective.

1.2 Method

This thesis consists of a literature review of relevant research on the topic of intrinsic motivation. A general selection of research articles, received from databases such as Web of Science and Google Scholar, were used to get an overview of the topic. To go further into intrinsic motivation and its neural correlates, keywords such as “the reward system”, “the undermining effect”, “intrinsic motivation”, and “neuro”, were used in the search. The articles that seemed most relevant to fit the aim of the thesis, depending on factors such as method and different aspects of the analyses, were selected. Additionally, articles from the past 10 years were used to minimize the risk of using less updated studies. Last, a comparison between the articles took place to see if the results were similar or contradictory.

The neuroimaging methods used in the chosen studies examining the neural substrates of intrinsic motivation are functional magnetic resonance imaging (fMRI), and positron emission tomography (PET). These imaging techniques enable measurement of psychological changes in the brain depending on people’s feelings, perceptions, actions and thoughts (Raichle, 1994). They help detect what brain areas are active during different cognitive tasks by identifying changing metabolism or blood flow in the brain when engaging in the task, as local blood flow rises in active parts of the brain. This makes these two methods particularly suited to the aim of the thesis. Some weaknesses of these neuroimaging methods are their poor temporal resolution in comparison with other recordings, and the difficulty to interpret each area’s functional contribution from the neuroimaging when some areas may be activated but still have no crucial role in the specific task that is performed (Gazzaniga, Ivry, & Mangun, 2016), which is also considered in the discussion.

2. Theoretical Background of Motivation

2.1 Self-Determination Theory

Over the last four decades, the Self-Determination Theory (SDT) has guided much research about motivation (Di Domenico & Ryan, 2017). Its main focus is the social-contextual conditions that enable or forestall the natural processes of healthy psychological development and self-motivation (Ryan & Deci, 2000). According to SDT, motivation is affected by three psychological factors: the need for competence, autonomy, and relatedness (Weinberg & Gould, 2014). Competence refers to the degree in which a person perceives herself as knowledgeable, efficacious and competent towards an activity. Autonomy means feeling ownership, freedom, and control over one’s values, feelings, and behavior. Relatedness refers to feeling connected and belonging to significant others by whom one wants to feel valued (Ryan & Deci, 2000).

Within SDT, two main reasons for engaging in various activities are described; intrinsic motivation and extrinsic motivation. Intrinsic motivation refers to authentic and self-authored striving towards a goal or a task, for the satisfying experience of it (Ryan & Deci, 2000). This means that one participates in the activity for no other reward than the activity itself and the subjective positive effect it induces. Examples of such activities include solving puzzles, singing, and hiking. Playful and explorative behavior among children also seems to fit into intrinsically motivated activities (Kaplan & Oudeyer, 2007). Extrinsic motivation refers to striving towards a goal or a task for the external rewards (e.g. money or social acceptance) (Ryan & Deci, 2000). Factors such as enhanced learning, creativity, performance, optimal development, and well-being have been shown to result from intrinsic motivation, rather than extrinsic motivation (Di Domenico & Ryan, 2017; Ryan & Deci, 2000).

A sub-theory within SDT is the organismic integration theory (OIT). Its main purpose is to describe the different types of motivated behavior and the aspects that either prevent or promote the internalization of it. This is illustrated by the self-determination continuum (Deci & Ryan, 2002). To the left of the continuum is amotivation, referring to lack of motivation and willingness to engage in an activity as a result of e.g., not valuing the activity or not feeling competent enough to do it (Ryan & Deci, 2000; Litalien et al., 2017). Next to amotivation are four types of extrinsic motivation along the continuum. The closest one is externally regulated which is the least autonomous, referring to engaging in a task to satisfy external demands. The externally regulated behavior is often perceived as controlled, with an external locus of causality and it is at the lowest level of internalization. Next to externally regulated behavior is introjected regulation, which is controlled from inside the person, but it is still regulated by external contingencies, hence the regulation may not be fully perceived as one's own. The reason for such behaviors can be to avoid a negative outcome or to attain ego enhancements. Next is identified regulation, which means behaviors that are accepted, chosen and valued as important for oneself, but not necessarily perceived as pleasant. Integrated regulation is the last and most autonomous form of extrinsic motivation. When this occurs, the behavior is personally important and is an expression of one's values and needs. Integrated regulation is often seen as similar to intrinsic motivation, however, the reason for the activity is the outcome rather than the inherent enjoyment of it which makes it a type of extrinsic motivation (Ryan & Deci, 2000; Selart, Nordström, Kuvaas, & Takemura, 2008). Finally, to the right of the continuum is intrinsic motivation. Some measures in the academic area have further divided this regulation into three parts: Knowledge: motivation comes from the joy of learning, exploring and to understand new things. Accomplishment: motivation comes from the satisfaction of exceeding oneself or mastering a new skill. Stimulation: engaging in an activity for sensory pleasure, excitement, or enjoyment (Litalien et al., 2017).

2.2 Theoretical Background of Intrinsic Motivation

Harlow (1950) documented the effect of intrinsic motivation in a study examining the behavior of rhesus monkeys when playing with mechanical puzzles. He observed that the monkeys continued to play the puzzle even when external rewards were absent. He further observed that the monkeys receiving external rewards got less spontaneous manipulative explorational behavior than the ones that did not receive any reward (Harlow, 1950).

White (1959) coined the concept of competence and saw the influence of optimal challenge in a task on intrinsic motivation. Optimal challenge is also a central part in Csikszentmihalyi's (1990) concept of flow, which is closely related to SDT's intrinsic motivation. When experiencing flow, one becomes totally absorbed in an activity and experience a non-self conscious enjoyment from it. The flow activity is exercised for its own sake and it is experienced with an inherent satisfaction (Di Domenico & Ryan, 2017). Factors that are central in the flow experience are balance between the challenges of the task and the ability of the exerciser, to feel in control of the activity, total concentration and focus on the activity, clear goals, the activity is intrinsically rewarding, loss of self-consciousness and sense of time, direct feedback of action results, and all awareness goes to the focus of the activity (Klasen, Weber, Kircher, Mathiak, & Mathiak, 2011).

Loewenstein (1994) proposed an "information gap" perspective, collecting insights of curiosity. According to this perspective, curiosity develops when attention is drawn to gaps in knowledge between what people want to know and what they actually know. Curiosity seeking is a form of self-directed learning and Loewenstein (1994, p. 87) define curiosity as "an intrinsically motivated desire for specific information". Piaget (1971) had a similar view of cognitive development in which he emphasized the inherent functions to gain new information or improve knowledge and skills. These inherent functions can be put in the same category with intrinsic motivation. Piaget (1971) described curiosity in a continuum which involves several steps and as a solution to a problem appears, so too do new problems, opening new ways for curiosity (Di Domenico & Ryan, 2017). The concept of plasticity also contains similar characteristics as intrinsic motivation and can be found in the Big Five model of personality (Di Domenico & Ryan, 2017). The meta-trait plasticity concerns the different exploratory directions of people and how prone a person is to find new environmental possibilities and experiences. It refers to how flexible the personality system is to generate and reach new goals (DeYoung, 2010). Curiosity is a specific marker of plasticity and it has also been found to almost universally be a positive predictor of behavioral frequency such as going dancing, writing a love letter, and making a new friend. People with high plasticity are also hypothesized to explore for its own sake, even when it may not further any goals, or seeing the exploration as the goal in itself (DeYoung, 2013). DeCharms (2013) emphasized the importance of personal causation for intrinsic motivation: it is important to have an internal perceived locus of causality of one’s actions.

Behaviorally, intrinsic motivation is often evaluated from freely pursued activities. Experimentally, self-report questionnaires are often used, concerning the reasons one may have for engaging in an activity. Questionnaires may also concern specific affective states such as curiosity, interest, and fun (Di Domenico & Ryan, 2017). Laboratory examinations of intrinsic motivation have also been made through recordings of specific exploratory behaviors and facial displays of interest when engaging in an intrinsically motivating activity, and how they correspond to self-reports (Reeve & Nix, 1997).

2.2.1 Cognitive Evaluation Theory. Cognitive Evaluation Theory (CET) is a sub-theory to SDT and its purpose is to explain the factors that undermine or facilitate the progress of intrinsic motivation (Weinberg & Gould, 2014). According to Mandigo and Holt (2000), it consists of four main propositions. First, an activity ought to be self-determined (autonomous) to be intrinsically motivating. One needs to feel in control when attempting to achieve personal goals in these activities. If an activity is perceived as externally controlled, most likely intrinsic motivation will decrease (Mandigo & Holt, 2000). This was tested in a study examining how different teaching styles might affect motivation in a sports activity. The participants reported higher levels of intrinsic motivation when they were given choices during the occasions rather than when the teacher made all decisions (Goudas, Biddle, Fox, & Underwood, 1995). Similar results have been seen in other studies (Mandigo & Holt, 2000).

Second, the challenge of activity ought to be balanced with one's abilities, being optimally challenging. This, in turn, leads to enhanced perceived competence (Mandigo & Holt, 2000). Danner and Lonky (1981) demonstrated how children would choose to engage and spend more time in tasks that suited their abilities. These tasks were also rated as more interesting than tasks that were perceived as too easy or too difficult.

The third part addresses how extrinsic factors can affect intrinsic motivation. Research has shown that extrinsic factors such as constructive and positive feedback with respect to competence enhance intrinsic motivation. Amotivational, or controlling factors, on the other hand, weaken intrinsic motivation. Further, rewards used to control behavior in an activity diminishes the likelihood of the person continuing with the activity without the rewards, as opposed to originally doing the activity in the absence of rewards (Mandigo & Holt, 2000). This undermining effect on intrinsic motivation is further explained later in the thesis.

Fourth, a person's mental orientation for an activity affects intrinsic motivation. Being task-involved (i.e. participating in an activity for the sake of enjoyment and focusing on the process) correlates with higher intrinsic motivation. On the opposite side of task-involvement is ego-involvement, which induces an internal pressure to nourish self-esteem of which one may feel controlled, reducing intrinsic motivation. When a person is ego-involved, she believes that her self-worth is defined by her performances (Duda, Chi, Newton, & Walling, 1995; Mandigo & Holt, 2000). What affects whether one is task-involved or ego-involved is often experience. Task-involvement will more likely result when being allowed to engage in more freely chosen activities. However, being told from an early age that one's self-worth is dependent on one's performance will, in turn, generate ego-involvement (Mandigo & Holt, 2000).

3. Motivation and Neuroscience

3.1 The Reward System

According to Hidi (2016) rewards are viewed differently in different areas of science. Psychologists view rewards as what one receives after doing something, as an externally controlled compensation. Neuroscientists, on the other hand, see them as positive reinforcements that raise the chances of a wanted behavior repeating itself. They further emphasize rewards as primary motivators of behavior, and important parts in control of decisions, actions, goal-directed behavior, and learning. According to Fareri, Martin and Delgado (2008) going after experiences that are rewarding motivates everyday human behavior.

Cognitive neuroscientists seek to identify the neural substrates of reward-seeking behavior (Galvan, 2010). The reward system is the brain structures in which reward processes take place (Hidi, 2016). Critical components of this system are the ventral tegmental area (VTA) in the midbrain, the striatum (especially the nucleus accumbens), the ventromedial prefrontal cortex (VMPFC) and the dopaminergic projections that come from the VTA and innervate these areas (Di Domenico & Ryan, 2017). The reward system was first discovered by Olds and Milner (1954) when they implanted an electrode in a rat's brain in structures near the medial forebrain bundle and nucleus accumbens (Berridge & Kringelbach, 2011). When these structures were stimulated by the electrode, the rat behaved energized. The next day, the rat returned to the spot in which stimulation had occurred. When given the opportunity to self-administer stimulation through pressing a bar, the rat was observed to work hard keeping the stimulation going. This phenomenon of working till exhaustion for stimulation of some areas of the brain is called self-stimulation and has been seen in many mammalian species, including humans (Hidi, 2016). The stimulated areas that result in this behavior all have in common that they are involved in dopaminergic pathways which begins in the VTA (Gazzaniga et al., 2016; Walter, Abler, Ciaramidaro, & Erk, 2005). These observations laid the path to further investigations on dopamine release and the role that dopamine have in subjective pleasure in the reward system. However, this idea has been changed by findings that indicate that dopamine is more connected to the expectancy or wanting of pleasure rather than the actual pleasure (Gazzaniga et al., 2016; Hidi, 2016). According to Berridge & Kringelbach, (2008) the main components of rewards are “liking” (the actual pleasure of the reward), “wanting” (motivation for reward), and “learning” (associations and predictions about rewards based on previous experiences). Berridge (2012) further emphasize that although “wanting” is often linked to “liking” for the same reward, they can also be separated. The feelings of pleasure from the use of many potentially addictive drugs is what encourages users to take them again. However, as a drug addiction increases, the pleasure from taking the drug decrease. Hence, the drug seems to be “wanted” more but “liked” less (Robinson & Berridge, 2008). Using fMRI, a study was conducted to investigate the reward system of the human brain on cocaine addicted subjects. The brain was imaged five minutes before and 13 minutes after cocaine injection while the participants rated on scales how high, low, and how much rush and craving they felt. The experimenters could see that high ratings of craving (wanting) correlated with activation in the ventral striatum, whereas high ratings of rush (liking) correlated with activation in the dorsal striatum (Breiter et al., 1997). The putamen and the caudate nucleus are the main components of the dorsal striatum and its signals are received from the dorsolateral prefrontal cortex and other frontal regions surrounding it. The ventral striatum receives most signals from ventral frontal regions and consists mainly of the nucleus accumbens. It is also connected to the amygdala, which process emotions, and other limbic areas. Furthermore, the striatum has shown to integrate information about motivation (Delgado, 2007).

3.2 The Undermining Effect

Many would naturally think that mixing intrinsic and extrinsic motivation should, in turn, produce more motivation, i.e. that adding extrinsic rewards (e.g., money) to something that is intrinsically motivating (e.g., singing) should enhance motivation. Early researchers had this view of extrinsic and intrinsic motivation; the more, the better. Researchers started examining the relationships between extrinsic and intrinsic motivation in the late 1960s, and today it is known that extrinsic rewards often reduce intrinsic motivation. This phenomenon is called the undermining effect (Weinberg & Gould, 2014).

Deci (1971) conducted a study examining the undermining effect in which 24 introductory psychology students were asked to solve a puzzle that had been shown to be intrinsically motivating. This took place during three sessions in which all participants were treated the same, the only difference was that half of the group were paid for doing the puzzle in the second session. In the third session, the participants that had previously been paid for doing the puzzle spent significantly less time on doing the puzzle compared with the participants that had never received any money for doing it (Deci, 1971). Deci, Koestner and Ryan (1999) did a meta-analysis on 128 studies examining how extrinsic rewards affect intrinsic motivation. As in the previously mentioned study conducted by Deci (1971), the undermining effect is often examined by having two groups engage in an intrinsically motivating task, where one group receives a reward and the other does not. A free-choice period is often included in the experiment where the participant is free to continue with the task if she wishes to do so. The intrinsic motivation is determined by the amount of time that is spent on the task in the free-choice period, and the participants are considered to have been affected by the undermining effect if the rewarded group spends less time on the task in the free-choice period as compared with the other group (Deci et al., 1999; Murayama, Matsumoto, Izuma, & Matsumoto, 2010). The meta-analysis showed that self-reported interest and intrinsic motivation were undermined from most extrinsic rewards, however with the exception that positive feedback induced intrinsic motivation, shown through induced free-choice behavior and self-reported interest (Deci et al., 1999).

Murayama et al., (2010) conducted a study examining the neural correlates of the undermining effect using fMRI. 28 participants were randomly assigned to either a stopwatch task (SW) or a watch-stop task (WS). The former task was more interesting and intrinsically motivating than the latter. The task was conducted in two sessions and before the first session the SW (reward) group were told that they would receive a performance based reward in form of money, the WS (control) group received money for task participation (not performance based) after the first session. In the second session, all participants were told that they would receive no reward. During the free choice period, participants in the control group spent significantly more time on SW than the reward group, which indicates presence of the undermining effect. The fMRI scans from the first session showed high activation in the anterior striatum in both groups, however significantly higher in the reward group. During the second session, the control group showed similar striatum activity as before, the reward group on the other hand now showed significantly lesser anterior striatum activity than the control group. The midbrain and the lateral prefrontal cortex (LPFC) showed a similar pattern of activation in the scans. The diminished activity in the anterior striatum, midbrain and LPFC are highly correlated and the authors speculate that they are collectively related to the undermining effect (Murayama et al., 2010). As previously mentioned, the striatum, midbrain, and prefrontal cortex are central parts in reward processing (Di Domenico & Ryan, 2017; Hidi, 2016). The conclusions drawn from the neuroimaging results are that the reduced activation in the striatum and midbrain indicate how there no longer is a subjective value in engaging in the task when there is no performance-based reward. Furthermore, the LPFC has been shown central for preparatory cognitive control to achieve goals, which is regulated by task value. Hence, the reduced activity in the LPFC indicates how the participants are not motivated to show cognitive engagement in facing the task (Murayama et al., 2010).

3.4 Intrinsic Motivation and Neuroscience

Although intrinsic motivation has been a topic within the field of motivation for a long time, it is only recently that its neural substrates have become of interest for researchers to examine (Ryan & Di Domenico, 2016). Di Domenico and Ryan (2017) states that there are at least three interrelated reasons for using neuroscience methods when examining intrinsic motivation. First, since the brain mediates experience and behavior, it is also required to understand the neural systems supporting intrinsic motivation to gain a full understanding of it. Second, neuroscience can examine internal processes which self-reports and observations of behavior cannot do. Hence, neuroscience can provide new insights to the field that other methods cannot provide. Third, motivational processes can be investigated at a higher level of resolution when using neuroscience methods, which provides the ability to refine conceptual accounts for intrinsic motivation (Di Domenico & Ryan, 2017). Additionally, behaviors and actions that generate enjoyment despite lack of external rewards may be better understood when there is a better comprehension of the neural mechanisms generating intrinsic motivation. This may, in turn, improve educational performance (Miura et al., 2017). Next follows a review of studies aiming to understand the neural correlates of intrinsic motivation.

3.4.1 fMRI Findings. Lee et al. (2012) conducted a study to examine if there were any neural differences in intrinsic and extrinsic motivation using fMRI. 10 native English speakers who underwent education at the University of Iowa participated in the study. The participants were exposed to different phrases in conditions of intrinsic motivation, extrinsic motivation or a neutral condition. These phrases were presented in random order and could be: participating in a fun project (intrinsic motivation), participating in a money-making project (extrinsic motivation), or participating in a required project (neutral). When reading the phrases, the participants were asked to press one button if they wanted to do the activity they read, and another button if they did not want to do the activity. The fMRI results showed that the intrinsic motivation conditions generated right insular cortex activation, while the extrinsic motivation conditions generated activity in the right posterior cingulate cortex (PCC). It is hypothesized that insular cortex activity is related to emotional processing, but also particularly to feelings of inherent need satisfaction and feelings of pleasure through bodily sensations (Singer, Critchley, & Preuschoff, 2009; Lee et al., 2012; Goldstein et al., 2009). Activation in PCC, on the other hand, has shown associations with decision making and more so, reward-based decision making (Smith et al., 2009). The researchers conclude that the findings indicate how actions from intrinsic motivation are chosen more by interest and enjoyment, whereas actions from extrinsic motivation depend more on socially-acquired stored values (Lee et al., 2012).

Miura et al. (2017) conducted an fMRI study examining their hypothesis that intrinsic motivation is affected by an action-outcome contingency, meaning that behavior is controllable and the result of it can be evaluated by its feedback. This should, in turn, activate the reward system, reflecting the generation of intrinsic motivation. Data were analyzed from 27 participants. The experiment involved the previously mentioned stop-watch task (SW) by Murayama et al. (2010) in which the participants were asked to press a button within a specified rage of three seconds, stopping the timer as close as possible to the 3-s time mark. In each run, there were four different SW conditions to manipulate the presence of an action-outcome contingency: one with both controllability and presented outcome, representing the existence of the action-outcome contingency, one with only controllability, one with only presented outcome, and one with neither controllability nor outcome. When the task lacked controllability, the timer did not stop in accordance with when the button was pressed, and when it lacked presented outcome, the participant was not provided with a result. In the free choice experiment, participants choose to engage in the condition with both controllability and presented outcome significantly more than any other condition, indicating its greater degree of enjoyment. In this condition, specific neural activity increases were shown in the anterior cingulate cortex, thalamus, and cerebellar vermis regions, as well as bilateral striatal regions such as the globus pallidus and caudate nucleus and the ventral tegmental area in the midbrain. Based on these results, the researchers concluded that intrinsic motivation is correlated to activation of the reward system (Miura et al., 2017).

In a study conducted by Marsden et al. (2015), 43 participants were asked to engage in word problem solving while being scanned with fMRI. The participants were randomly assigned to either a reward group or a no reward group. The reward group was told that they would receive a performance-based bonus and the no reward group were not offered any bonus. Intrinsic motivation was measured by the percentage of time spent on the word problem solving during the free-choice time where more time spent on the word problem solving referred to higher intrinsic motivation toward it. This, in turn, resulted in a high-intrinsic group (N = 20), spending more than 50% of the free-choice time on the task, and one low-intrinsic group (N = 23), spending less than 50% of the free-choice time on the task. The groups were also equally distributed from the reward and no reward group. A distinct pattern of significantly diminished neural responses in the amygdala, caudate, ACC, parahippocampal gyrus (PHG), anterior insula, and posterior insula was identified in the high-intrinsic group compared to the low-intrinsic group. These regions have both separately and together been seen concerned in affective regulation, cognitive control, and learning (Marsden et al., 2015).

Lee and Reeve (2017) conducted a study using two tasks to induce high vs low intrinsic motivation among 22 participants. The first task involved curiosity inducing (intrinsically motivating) versus low curiosity-inducing question answering (non-intrinsically-motivating). This was inspired by Loewenstein (1994) and his previously mentioned information-gap perspective where the low curiosity-inducing question had easy answers and thus resulting in no information gap or satisfaction of filling in the missing information. In contrast, the curiosity inducing questions concerned new information which induces anticipation of pleasure and satisfaction from searching for and finding the missing information. The second task involved competence-enabling (intrinsically motivating) versus non-competence-enabling anagram solving (non-intrinsically-motivating). Here the participants were asked to form words from jumbled letters. In the non-competence-enabling condition, the jumbled letters were similar to the real word making it less interesting. The letters in the competence-enabling condition were more jumbled and not similar to the real word, it was also controlled to be interesting and not too difficult. The procedure was scanned with fMRI and the results showed increased activation in both bilateral anterior insular cortex (AIC) and the striatum when the participants performed the intrinsically motivating tasks. This effect had also been hypothesized by the researchers. In addition, increased activity in the left thalamus, bilateral cerebellum, bilateral dorsolateral prefrontal cortex (DLPFC), right medial frontal gyrus, left precentral gyrus, left angular gyrus, and right occipital lobe was also seen when performing the intrinsically motivating tasks. A positive interaction was seen between AIC and striatum during the intrinsically motivating tasks. This connectivity has also been seen in previous scientific studies. The conclusion that the researchers drew from these results is that the AIC and striatum work together, rather than individually, in the intrinsic motivation system. The researchers further argued that the increased activity in the frontal areas (e.g., DLPFC, medial frontal gyrus) that were observed during intrinsic motivation indicates that intrinsic motivation may play a role in mobilizing cognitive processes during task performance, on the basis that these areas are well-known regions for higher-order cognitive processes (Lee & Reeve, 2017).

To investigate the neural correlates of intrinsic motivation when it is affected by verbal or monetary rewards, an fMRI study was conducted in which 64 participants were asked to solve picture puzzles. The participants were randomly assigned to either a verbal reward group, a monetary reward group, or a control group. In the first period, all participants were asked to solve the picture puzzles as a baseline condition, in which they received feedback in terms of success or failure. This condition was the same for all groups. In the second period, the monetary reward group was told that they would get paid for each correctly solved puzzle. The verbal reward group instead received encouraging feedback after each correctly solved puzzle. The control group had no changed condition from the first period. In the third period, all groups were again presented to the baseline condition, the monetary group was told that they would not receive any payment from this period and the verbal reward group received no encouraging feedback. In the second period, the results showed increased activity in the anterior striatum and midbrain in both the verbal reward group and the monetary reward group compared with the control group. In the third period, it was hypothesized that there would be a decreased activation in these areas in the monetary reward group due to reward withdrawal, based on the previously mentioned study conducted by Murayama et al. (2010) on the undermining effect. Yet no such decrease was seen. However, even higher activation was seen in these areas in the verbal reward group during the third period, when they received success compared to failure feedback. Additionally, the right lateral prefrontal cortex (rLPFC) had enhanced activation in the verbal reward group in the second and third period of doing the task (Albrecht, Abeler, Weber, & Falk, 2014).

In a study conducted by DePasque and Tricomi (2015), 25 participants completed two sessions of a word association learning task while given feedback after two thirds of the learning phases. The participants were asked to complete the first session of the word association learning task, they then went through a brief motivational interview. Motivational interviewing is a counselling style and is a strategy for enhancing intrinsic motivation (DePasque & Tricomi, 2015; Miller & Rollnick, 2013). They were then asked to complete the second word association learning task. The participants were also asked to rate their motivation during the sessions. They used fMRI to investigate the interaction between feedback processing and intrinsic motivation during the sessions. The motivation levels throughout the scanning were linked to negative versus positive feedback in the striatum. Enhanced motivation after the motivational interview also correlated with increases in feedback sensitivity in the left medial temporal lobe. Additionally, the subjects who reported greater motivation after the motivational interviewing showed an increasing valence sensitivity in the left anterior parahippocampal gyrus. This motivational modulation of the parahippocampal gyrus is coherent with previous evidence that knowledge about the motivational significance of information is processed by dopaminergic projections from the midbrain to the medial temporal lobes. The parahippocampal gyrus has been shown involved in associative encoding of arbitrary pairs of objects, emotional memory encoding, and memory retrieval. For instance, higher confidence for remembering an item generates higher activation in the parahippocampal gyrus in recognition tests. The experimenters of the study speculate that the region may have been involved in the learning and recalling in the word association learning task. Becoming better at recalling the right answers with high confidence, which is correlated with higher activation in the parahippocampal gyrus, may be a result of increased motivation. The researchers concluded that the results indicate how neural responses to performance-related feedback are modulated by motivation, and areas involved in memory and learning are enhanced by motivation. Additionally, the participants that increased their intrinsic motivation most also achieved greater gains in performance from the first to the second task. Thus, increased performance seems to depend on how much the intrinsic motivation increased after the motivational interviewing manipulation (DePasque & Tricomi, 2015), which is consistent with earlier mentioned beneficial effects of intrinsic motivation.

Guided by Loewenstein's information-gap theory, Kang et al., (2009) conducted a study to examine the neural correlates of curiosity using fMRI. The participants were presented with a range of trivial questions varying in degree of curiosity. They were asked to read each question, give their answer, rate their curiosity of the question and their confidence in their answer. The question was then presented again with the correct answer. The results showed that higher reported curiosity was correlated with greater activity in the left caudate, parahippocampal gyri (PHG) and bilateral prefrontal cortex (PFC). When it was revealed that the responses were incorrect and the real answers were shown, curiosity among the participants correlated with greater activity in the left PGH and in the midbrain (Kang et al., 2009).

3.4.2 Dopaminergic Pathways. The complex cognitive, behavioral, and affective phenomenon that is intrinsic motivation is likely connected to several neural structures and processes (which one also can conclude from the previous section). Hence, examining the neurotransmitter systems involved in intrinsic motivation may be useful in understanding the neurobiology of it (Di Domenico & Ryan, 2017).

Dopamine seems to be a basic key of intrinsic motivation based on three lines of evidence. First, intrinsically motivating elaborative behaviors are connected to activation of the previously mentioned reward system of which dopamine plays a crucial part (Di Domenico & Ryan, 2017). Second, both dopamine and intrinsic motivation are likewise associated with cognitive flexibility, positive affect, creativity (Ashby, Isen, & Turken, 1999), exploration (DeYoung, 2013), and behavioral persistence (Di Domenico & Ryan, 2017). Third, some evidence shows the direct link between dopamine and intrinsic motivation. A study was conducted to investigate the relationship between the availability of dopamine D2-receptors in the striatum and the experience of the intrinsically motivating flow state. To measure the striatal D2-receptor availability, positron emission tomography (PET) was used on a sample of 25 participants and the Swedish Flow Proneness Questionnaire was used to identify their flow proneness. The results showed a significant correlation between flow proneness and D2-receptor availability, people that were more prone to experience flow also possessed a higher dopamine D2-receptor availability in striatal regions, especially the putamen (De Manzano et al., 2013). Additionally, another study found that carriers of a genetic polymorphism report higher flow proneness when related to study and work activities. In turn, this polymorphism has been shown to affect striatal D2 receptor availability. These results support the idea that flow proneness is related to dopamine D2 receptor availability in the striatum (Gyurkovics et al., 2016).

Murayama et al. (2013) asked 31 participants to participate in the previously mentioned stop-watch task (Murayama et al., 2010). Enhanced performance has been seen as a result from self-determined, autonomous choosing, and the aim of this study was to investigate the neural correlates of this beneficial phenomenon using fMRI, focusing mainly on the outcome feedback period. In this study, the participants were randomly assigned to a self-determined choice or a forced-choice condition. In the self-determined choice condition, the participants selected themselves the appearance of the stop-watch task which they wanted to conduct. The participants in the forced-choice condition were instead assigned to a stop-watch task by a computer, without the opportunity to choose. Despite no difference in difficulty between the groups, the results indeed showed enhanced performance in the self-determined choice condition. Additionally, the fMRI scanning showed activity in the ventromedial prefrontal cortex (vmPFC) from both success and failure feedback in the self-determined choice condition, whereas vmPFC activity decreased from failure feedback in the forced-choice condition. This vmPFC resilience to failure feedback was correlated with the enhanced performance in the self-determined choice condition (Murayama et al., 2013). Value coding dopamine neurons have been suggested to transmit from the midbrain to the vmPFC. This structure has also been seen as a part of learning from negative reward prediction errors and updating outcome expectations during learning. These findings are confirming the idea that intrinsic motivation and the autonomy which it consists of, is connected to activity in the dopaminergic value system (Di Domenico & Ryan, 2017).

Based on their previous experience with video games, 13 participants were voluntarily recruited in a study examining the neural correlates while playing a video game. The factors that were analyzed were balance between ability and challenge, concentration and focus, direct feedback of action results, clear goals, and perceived control over the activity. These factors are correlated with the experience of flow. Greater activity in the putamen, caudate and the nucleus accumbens was seen as a result of optimal challenge. Decreased activity in the ACC and orbitofrontal cortex correlated with goal clarity and high focus (Klasen et al., 2011). These findings are consistent with the idea that intrinsic motivation is associated with dopaminergic signaling and suppressed activity in default mode regions (Di Domenico & Ryan, 2017). Additionally, high perceived control over the activity correlated with activity in thalamic, visual, cerebellar and motor-cortical regions. No activation pattern was detected from direct feedback of action results. To see if these intrinsically motivating flow factors have similar neural networks, conjunction analyses were designed to detect overlaps in the brain correlates. Since no activation pattern was detected from direct feedback of action results, this factor was excluded. The conjunction analyses of the remaining four factors showed shared somatosensory and motor system activation. These findings show the importance of sensory-motor simulation to flow in video games (Klasen et al., 2011).

Ulrich, Keller, Hoenig, Waller and Grön, (2014) conducted a study in which 27 participants were asked to perform mental arithmetic tasks with three different levels of challenge. The boredom condition consisted of a low level of task challenge, the flow condition had a challenging task difficulty that was dynamically adapted to the participants' individual skill level, and the overload condition consisted of a very high level of task challenge. The results demonstrated increased activity in the left putamen, the left inferior frontal gyrus (IFG) and posterior cortical regions in the intrinsically motivating flow condition. In this condition, there was also significantly decreased neural activity in the left amygdala and the medial prefrontal cortex (MPFC). The increased activity in the putamen is consistent with the previously mentioned relationship between flow proneness and D2 receptor binding in the striatum. Further, activation in IFG has been correlated with sense of control, which is also a feature of the definition of flow and intrinsic motivation. The decreased neural activity in the MPFC suggests suppressed default mode network activity (Ulrich et al., 2014). Additionally, Yoshida et al., (2014) examined activity in the prefrontal cortex when in the flow state or in boredom while the participants played Tetris. These results showed increased activity in the lateral PFC when experiencing flow (Yoshida et al., 2014).

4. Discussion

This thesis set out to investigate the neural correlates of intrinsic motivation. First of all, we presented a background review of motivation and intrinsic motivation going through central parts in the area such as the Self-Determination Theory, flow, the information-gap theory, plasticity, and the Cognitive Evaluation Theory. This was followed by a chapter on motivation and intrinsic motivation from a neuroscientific perspective, concerning concepts such as the reward system, the undermining effect, and studies examining the neural correlates of intrinsic motivation in different ways. At first glance, the findings of neural activity connected to intrinsic motivation seemed to vary much between the different studies and to involve activity in many different brain areas. However, most studies indicated involvement of dopaminergic pathways with activation in prefrontal regions and even more in striatal regions when the participants were intrinsically motivated. As previously mentioned, these areas are central parts in the reward system which suggest that the reward system is involved when intrinsic motivation is being processed. However, the midbrain is also a central part of the reward system and only a few studies showed activation in this area when intrinsic motivation was present. Additionally, it may be a mistake to associate intrinsic motivation exclusively to the reward system given that almost all studies also showed activity in other areas (though not as frequently as in the striatal and prefrontal regions). Also, there was one study that showed no correlations to parts of the reward system (Lee et al., 2012). However, this study differed from all other studies quite drastically. While all other studies involved engaging in intrinsically motivating activities, this study involved only reading phrases of such activities (Lee et al., 2012). Even though evidence has shown that imagining an activity generates similar brain activity as when doing the actual activity (Olsson, Jonsson, & Nyberg, 2008; Pascual-Leone et al., 1995), reading phrases of intrinsically motivating activities may not have the same effect. For imagery to work effectively it must be detailed and the person ought to have a certain experience or knowledge of the imagined activity (Weinberg & Gould, 2014). Considering that the participants were only presented with simple phrases of activities and were to press one button if they wanted to do the activity they read, and another button if they did not want to do the activity, the descriptions were not detailed, and no previous experience of the described activities was considered. Hence, the findings from this study seem quite insufficient in the context of this thesis and in the aim of revealing the neural correlates of intrinsic motivation.

Activity in some brain areas was only seen in one or a few studies of intrinsic motivation, which makes it very questionable that these areas are involved in the phenomenon per se. A possible explanation for this rarely shown activity (e.g., the right occipital lobe or the left medial temporal lobe) when the participants were intrinsically motivated might be because the studies involved different tasks. Considering that all studies were conducted under different circumstances and involving different tasks, one should not expect that the results of brain activity would all be the same. It would be incorrect to assume that these areas are involved in intrinsic motivation at this stage based on simply one or a few studies when most of the studies showed no such activity. Thus, it is concluded that these areas were activated for other reasons, due to lack of control in the studies, and are thus quite unimportant in the process of intrinsic motivation.

4.1 Contradictory Findings

Contradictory results were shown when some brain areas in a few studies showed diminished activity while the same areas showed increased activity in other studies, correlated to intrinsic motivation. Diminished neural response in ACC was seen in two studies whereas one study showed increased activity in this area, when the participants were intrinsically motivated. The study in which increased ACC activity was seen, examined how intrinsic motivation was affected by an action-outcome contingency in the stop-watch task (Miura et al., 2017). In the intrinsically motivating condition, which involved both controllability and presented outcome, ACC and other areas were more activated than other areas. On the basis that ACC activity has been shown to be involved in learning to predict the likelihood of error, the researchers suggested that the ACC activation reflected the expectation of task error as represented by the predicted difference between stopped times and target (Miura et al., 2017). The first study that showed decreased ACC activity connected to intrinsic motivation involved engaging in word problem solving. The researchers noted that they were unable to point out the specific contributions of this decreased activity to intrinsic motivation. However, they did state that these findings (consistent with other data), showed that decreased activation in neural affective and cognitive control (which ACC is involved in) may increase intrinsic motivation (Marsden et al., 2015). The second study that showed decreased ACC activity was when participants had goal clarity and high focus when playing a video game. The researchers speculated that this reflected a suppression of emotions that were non-task relevant and distracting. This factor may be important for the player to shift his focus on task-relevant factors which will increase his performance (Klasen et al., 2011). Additionally, Di Domenico and Ryan (2017) speculate that these findings are consistent with the idea that intrinsic motivation is associated with suppressed activity in default mode regions. The default mode regions, or the default mode network, is a group of brain regions that are more activated when a person is cognitively "at rest" and not thinking about anything specific. It consists of the medial temporal lobe, medial prefrontal cortex (which contain the ACC), precuneus, temporoparietal junction, lateral parietal cortex, posterior cingulate cortex (Gazzaniga et al., 2016).

The study by Marsden et al. (2015) further differed from other studies showing only decreased activity in brain areas whereas other studies showed more increased activity, correlated to intrinsic motivation. Two of the areas that showed decreased activity connected to intrinsic motivation in this study were the caudate and the parahippocampal gyrus (PHG) (Marsden et al., 2015). However, three other studies showed increased activity in the caudate (Kang et al., 2009; Klasen et al., 2011; Miura et al., 2017), and as earlier mentioned even more in the striatum overall. Two other studies showed increased activity in the PHG (DePasque & Tricomi; Kang et al., 2009). Marsden et al. (2015) had the same conclusion for all areas with diminished activity: they were unable to point out the specific contributions of the decreased activity connected to intrinsic motivation. Yet, they did state that these findings showed that decreased activation in neural affective and cognitive control may increase intrinsic motivation (Marsden et al., 2015). However, this conclusion seems quite vague considering that the decreased activity in all areas is explained in the same way, and most other studies show contradictory results. Additionally, the journal Cognitive, Affective, & Behavioral Neuroscience that published this article has an impact factor of 2,6, whereas the journals that published the contradicting findings have impact factors ranging from 3,4 till 6,1 (Social Cognitive and Affective Neuroscience, Neuroimage, and Psychological Science) (DePasque & Tricomi; Kang et al., 2009; Klasen et al., 2011; Miura et al., 2017), implicating further the strength these studies have compared to the study conducted by Marsden et al. (2015).

4.2 Criticism

As SDT and intrinsic motivation have for a long time been a topic within the field of psychology, some literature of criticism or contradicting opinions has developed over the years. Next there will be a presentation of this literature.

For over 40 years, Reiss (Reiss, 2005; Reiss & Sushinsky, 1975, 1976) has claimed the undermining effect to be both ideologically inspired and scientifically unsupported (Hidi, 2016). The first argument that Reiss (2005) raises is that the undermining theorists have not shown construct validity for the central ideas of intrinsic motivation. These central ideas are competence, the neurophysiological distinction between extrinsic and intrinsic motivation, intrinsic motivation defined as the pursuit of enjoyment, and the idea that intrinsic motivation is doing a desired action, whereas extrinsic motivation is acting to get something else. Constructs such as play, curiosity, achievement motivation (being task-involved) and self-determination are very dissimilar, they may not have much in common and does not necessarily correlate with each other. Reiss (2005) further states that the neurophysiological distinction between extrinsic and intrinsic motivation, or the internal-external definition, is based on anecdotal observations. This definition imply that the environment produces extrinsic motivation, while intrinsic motivation comes from internal factors. The definition which states that intrinsic motivation is the pursuit of enjoyment, Reiss (2005) calls the hedonistic definition and argues that enjoyment is individual and dependent on the person's motive, desire, or need. If anticipation of intrinsic pleasure motivates behavior, one could for instance hike until exhaustion if hiking is intrinsically pleasurable. Getting more tired would then make the person want to hike even more to get the enjoyment of pleasure. However, if one is tired one may instead want to rest and then instead dislike hiking. Intrinsic motivation is doing a desired action, whereas extrinsic motivation is acting to get something else. This is what Reiss (2005) calls the means-ends definition by which he means that there may be competing interests of behaviors. The idea here is that means do not undermine ends, but they rather facilitate them. Means and ends do not compete. For instance, a means for experiencing honour is doing one's duty, which does not compete with pursuing honour. Hence, this means-ends definition cannot predict the undermining effect. Reiss further states that motivation is fundamentally multifaceted and has plenty of categories, instead of just intrinsic and extrinsic motivation (Reiss, 2005).

Reiss's second argument is measurement unreliability. Some studies that showed no undermining effect have been explained by other factors such as the unreliability of the free-choice measures or that the participant's expectations made the study irrelevant. In this way, the undermining effect is supported no matter the outcome. Additionally, follow-up sessions are not used by the researchers to see a stable baseline and reliability of measurement on the participants. Reiss also questioned the self-report measures used in some studies, which he thought were too thin, only asking one or two questions about how much they liked the activity, with unknown psychometric properties (Reiss, 2005). This has also attracted the attention of other interest researchers who have questioned such interest measures. Feelings seen as indicators of participants' motivation means accepting that self-report measures always deliver the truth and ignoring other components. Additionally, the earlier mentioned research by Berridge (2012) according to whom the main components of rewards are liking, wanting and learning, support Reiss (2005) in saying that feelings alone are not indicators enough of reward-related motivation (Hidi, 2016).

The third argument raised by Reiss is that there are inadequate experimental controls. In studies examining the undermining effect, only one or a few conditions with rewards have been used. This is a lack of experimental controls and might have an impact on the results in the studies. Different results might be seen if the studies would use several conditions with rewards, which might minimize the discovered negative effects of rewards (Reiss, 2005). Smith and Pittman (1978) conducted a study which showed that the undermining effect might appear from distractions. Consequently, it is crucial that distractions are controlled for, so the researchers know that the result arose due to the undermining effect and not due to distractions. Further, all negative effects of rewards need to be controlled for, such as performance anxiety, frustration, and distraction (Reiss, 2005). Smith and Pittman (1978) also demonstrated that the effects of rewards are often not the same after one reward as after having received rewards over a period of time, such as a student receiving grades continually or a professional athlete getting paid 12 times per year (Reiss, 2005). Pretty and Seligman (1984) demonstrated how affect strongly influences the undermining effect. Manipulating the positive or negative affect of the participants when engaging in a specific activity either enhanced or reduced the intrinsic motivation for it. For instance, adding a reward to an activity that was already correlated with positive affect mitigated the harmful effects on the motivation for the activity. It was further concluded that negative affect might either in itself or as a reaction to evaluation processes and self-perception have a crucial damaging effect on intrinsic motivation. Additionally, neuroscientific research has indicated that motivation is not reduced by unexpected or intermittently delivered rewards (Hidi, 2016).

Reiss's last argument is that there are biased metareviews. When questioned about studies that do not show an undermining effect, undermining theorists have responded that these studies have methodological shortcomings and have reached for higher methodological standards for these studies, compared to studies that actually showed an undermining effect. Metareviews are also biased since they use studies with single-trial rewards (Reiss, 2005).

Reiss concludes that when there is so much going on at once, one can expect nothing consistent. Important variables that need to be taken into account are different activities, rewards, needs or motives, the intensity of reward and of interest in the target behavior, measurement, and details of the reward procedure. Uncontrolled variables such as frustration and distraction are also important to address. It is hard to draw stable conclusions when so many variables are so poorly controlled (Reiss, 2005).

Additionally, Cameron, Banko, and Pierce (2001) found that adding rewards for activities of low interest resulted in increased free-choice intrinsic motivation. They also found that when rewards were connected to performance, intrinsic motivation either stayed on the same level as the nonrewarded control participants, or it increased. Further, Cameron, Pierce, Banko, and Gear (2005) had participants engaged in a problem-solving activity in either a practice condition or a performing condition. In both conditions, the participants either received achievement rewards or no reward. Level of intrinsic motivation depended on time spent on the task in the free-choice period and ratings of task interest. The major finding was that participants in the practice condition who had received achievement-based rewards had increased intrinsic motivation. The data also showed that interest-internal attribution and perceived competence were two factors that induced these results.

Eisenberger and Armeli (1997) examined the effects that monetary rewards had on the creative performance and interest of 416 preadolescent school children. In the first experiment, participants were asked to generate unusual uses for physical objects. The requirement of this novel performance in turn created greater subsequent creative performance in picture drawing, which was a completely different task, when the magnitude of reward was larger than when it was smaller or there was no reward. In the second experiment, intrinsic creative interest was measured based on the participant's decision to make original drawings rather than copying an already known drawing. The results showed that subsequent creative interest was enhanced when rewarded for novel performance but diminished when rewarded for uncreative performance. The researchers concluded that creativity is enhanced by salient rewards for novel performance and does not reduce any intrinsic creative interest. Eisenberger and Shanock (2003) reviewed the literature on the effect of rewards on intrinsic motivation and creativity and maintained this conclusion.

Additionally, two of the previously mentioned studies examining the neural correlates of intrinsic motivation did not seem to show any undermining effect. The study by Marsden et al. (2015), where participants were asked to engage in word problem solving showed that the participants that spent more than 50% of the free-choice time on the task (high-intrinsic group) were equally distributed from the reward and no reward group. From the undermining effect perspective, it would be expected that the high-intrinsic group would consist significantly more of participants from the no reward group. The study by Albrecht et al., (2014) also found some contradictory results from the undermining effect. This study investigated the neural correlates of intrinsic motivation when it is affected by verbal or monetary rewards when solving picture puzzles. In the second period, the monetary reward group was told that they would get paid for each correctly solved puzzle. The verbal reward group instead received encouraging feedback after each correctly solved puzzle. In the third period, the monetary group was told that they would not receive any payment from this period and the verbal reward group received no encouraging feedback. In the second period, the results showed increased activity in the anterior striatum and midbrain in both the verbal reward group and the monetary reward group. In the third period, it was hypothesized that there would be a decreased activation in these areas in the monetary reward group due to reward withdrawal, based on the undermining effect. Yet no such decrease was seen. (Albrecht et al., 2014). While the aim of these studies was not to examine the undermining effect, it is nevertheless interesting to acknowledge these findings.

Chemolli and Gagné (2014) argue that the earlier mentioned self-determination continuum in SDT is a confused description of the different types of motivation since they seem to differ across the SDT literature. Additionally, the motivational regulations seem qualitatively different, still SDT put them along a continuum of different degree of autonomy. Chemolli and Gagné argue that these motivational regulations differ more in kind than in degree which makes it incoherent to put it in a continuum of autonomy. The motivational regulations of the continuum ought to yield a single dimension in the use of factor analytic techniques to differ in degree instead of kind. Previous research has shown that the motivational regulations obtain multidimensional solutions and each factor represents one of the regulations. Consequently, regulations differing in degree should produce different levels of outcomes. However, it has been shown that different regulations instead yield different outcomes and not different levels of the outcome. E.g., one study showed all regulations to be associated with different patterns of strategies for coping, still only two were linked to anxiety towards school, whereas two were liked to enjoyment. Additionally, Chemolli and Gagné emphasize that a person can choose to engage in an activity for multiple reasons, involving different types of motivation. However, like a thermometer can only show one temperature at the same time, a person should only be able to be located on one spot of the continuum at the same time, given that motivation differs in degree and not in kind. E.g., a teacher working to make money may additionally do it because she finds the work to be enjoyable and of importance for her students. Hence, her motivation is external, identified, and intrinsic, simultaneously. Therefore, each regulation is more a continuum itself, such that each regulation is a thermometer, and not that all regulations align along the same continuum. This has been supported by findings showing that the regulations fall onto different dimensions. Chemolli and Gagné argue that SDT does not need a continuum structure and can instead describe the regulations as varying in kind instead of degree, which is the definition of a continuum. These factors are important to consider since this view of motivation affects how researchers estimate motivational scores. Using a more exact definition of motivation helps to see better operationalizations leading to more accurate results leading to enhanced applications of the theory (Chemolli & Gagné, 2014).

Another debate has been whether the correlation between well-being and intrinsic motivation can be globally generalized, or if this correlation is only present in “Western” culture (Vansteenkiste, Lens, Soenens, & Luyckx, 2006; Vansteenkiste, Zhou, Lens, & Soenens, 2005). For instance, studies has shown that Chinese students flourish and achieve good results in academic settings when under external pressure from teachers, parents or society (Markus & Kitayama, 2003). According to Markus and Kitayama (1991) motivation is influenced by the different views of the self and of others, which differ remarkably between some cultures. A central view in Japanese culture is the importance of interdependence of the self with others, to foster interpersonal harmony. North American culture, on the other hand, emphasize individualism, for each person to be separate and independent (Heine, Lehman, Markus, & Kitayama, 1999). Hence, researchers have argued that autonomy, which is a key part of SDT, is not as valued in Eastern societies as it is in Western societies (Vansteenkiste et al., 2005).

Additionally, what motivates people in different ways is subjective and may differ between individuals. This makes it a more complicated phenomenon to examine. There may also be different levels of intrinsic motivation. For instance, one intrinsically motivating activity might make a person do that activity till exhaustion, while another intrinsically motivating activity does not. It is of importance to acknowledge and control for these differences when examining intrinsic motivation.

4.3 Future Research

Since the neural correlates of intrinsic motivation is still a new area of investigation, more research needs to be done on the subject. For instance, brain areas that showed activity in some of the previously mentioned neuroscientific studies of intrinsic motivation, such as the thalamus (Klasen et al., 2011; Lee & Reeve, 2017; Miura et al., 2017), should be further examined to see if a particular area is indeed involved in intrinsic motivation or if it was activated from lack of control of other factors. Hence, as Reiss (2005) states, future research should control more for other factors such as performance anxiety, frustration, and distraction to be sure of what the neural activity reflects. If future research would continue to show activity in dopaminergic pathways such as the striatum and the prefrontal cortex connected to intrinsic motivation, this would strengthen the possibility of the connection between these factors which has been seen in current studies. Additionally, future research should investigate further the neural correlates of intrinsic motivation as well as the neural correlates of extrinsic motivation. Comparing the neural substrates that underlie these two phenomena will lead to a better knowledge of what brain areas are involved in both intrinsic and extrinsic motivation, but also hopefully show different patterns of activity, showing what areas are specific for each phenomenon.

4.4 Conclusion

As mentioned earlier, research about the neural correlates of intrinsic motivation can lead to a better understanding of the phenomenon. Considering the positive effects that emerge from intrinsic motivation, it is quite clear that a society in which people are more intrinsically motivated is a flourishing society. Hence, a better understanding of intrinsic motivation might lead to a better knowledge of how to enhance the phenomenon in different contexts such as in workplaces or in educational settings. Additionally, having people reflect on why they do things is a contemporary topic in society today where people seem very driven by social media.

The aim of this thesis was to examine the neural correlates of intrinsic motivation. The findings from several studies in the area indicate the involvement of dopaminergic pathways, mostly the striatum but also the prefrontal cortex area, connected to intrinsic motivation. The research and studies in themselves do not seem to have any greater ethical problems. However, if the studies' conclusions are wrong in lack of control, this may lead to ethical problems when applying this knowledge in a misleading way. Therefore, more controlled research is required to determine the neural correlates of intrinsic motivation, especially to clarify the role of the areas that only showed activity in some of the studies.

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