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NEURAL CORRELATES OF HEDONIC AND EUDAIMONIC HAPPINESS: AN fMRI STUDY ON HEALTHY SUBJECTS

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ABSTRACT

Positive Psychology is born in last decades and points its focus on human resources instead of illness and pathology, as done by traditional psychological studies. Happiness is one of the human resources that individual can pursuit in their life. The psychological study of happiness defined two tendencies that refer to two different conception of happiness. Hedonic happiness is what we feel during the experience of intense physical or psychological pleasure, while eudaimonic happiness is what we feel during experiences in which we reach our personal goals or we perceived to have expressed our potential, our abilities, or to be who we really are.

None study was found in the field of affective neuroscience investigating neural correlates of these two concepts of happiness. The purpose of this research is to investigate whether the psychological distinction reflects a distinction in neural patterns related to these two kinds of happiness.

Sample: 17 subjects (7 males, 10 females) aged between 20 and 40 years old (mean age: 25,06, SD =5,05). All of them were right-handed.

Instruments: during fMRI scanning, participants were guided, through the presentation of short sentences on a screen, to imagine happy events they had chosen within a list as the happiest whether happened in that moment. Three conditions were compared: eudaimonic events (EU), hedonic events (ED) and neutral events (NE).

Results: imagination of happy events from both kinds, compared to the imagination of neutral events, activates a core network comprising of frontal, temporal and parietal regions, as well as activations located in cerebellum and subcortical structures as amygdala and basal ganglia. In the direct comparisions was found increase of BOLD signal mostly in frontal medial/middle regions and anterior cingulate cortex, associated with rewarding the self, during hedonic happiness. Conversely, eudaimonic happiness principally activates right precentral gyrus, a region associated with action planning to reach a goal and cognitive reappraisal.

Conclusion: hedonic happiness makes subjects more involved with themselves and their internal world, while eudaimonic happiness requires cognitive sense-making and commits the subject to the external world. Therefore, we can claim that the two concepts of happiness linked the subjects to opposing perspectives. These preliminary results are interesting, help us to better understand the differences between the two presented psychological constructs, and encourage research on happiness, although they need future confirmation in larger sample and in subjects from different range of ages.

Keywords: emotion, hedonic happiness, eudaimonic happiness, fMRI, guided imagination

ABBREVIATIONS

ACC	Anterior Cingulate Cortex
Ach	Acetylcholine
AD	Alzheimer's Disease
BDN	Brain's Default Network
BOLD	Blood-Oxygenation-Level Dependent
dlPFC	Dorso Lateral Prefrontal Cortex
EEG	Electro Encephalografy
EU	Eudaimonic
FG	Frontal Gyrus
fMRI	Functional Magnetic Resonance Imaging
GLM	General Linear Model
HE	Hedonic
HF	Hippocampal Formation
HMA	High Motor Activation
IFG	Inferior Frontal Gyrus
INS	Insula
IPL	Inferior Parietal Lobule
LMA	Low Motor Activation
MEG	Magneto Encephalography
MIP	Mood Induction Procedure
mPFC	Medial Prefrontal Cortex
MTG	Middle Temporal Gyrus
nACC	Nucleus Accumbens
NE	Neutral
OFC	Orbitofrontal Cortex
PC	Parietal Cortex
PCC	Posterior Cingulate Cortex
PET	Positon Emission Tomography
PFC	Prefrontal Cortex
PrCG	Precentral Gyrus
rCBF	Regional Cerebral Blood Flow
Rsp	Retrosplenial Cortex
SMA	Supplementar Motor Area
SPECT	Single Photon Computed Tomography
TG	Temporal Gyrus
TPC	Temporo Parietal Cortex
vmPFC	Ventro Medial Prefrontal Cortex
VP	Ventral Pallidum
VS	Ventral Striatum
VTA	Ventral Tegmental Area

Contents

INTRODUCTION

Happiness is a complex psychological state, typically treated by affective neurosciences as an emotion. Psychological debate in recent years, especially with the development of positive psychology, turned around two concepts of happiness that define two main aspects of this emotion: hedonic and eudaimonic happiness.

Hedonic happiness is what we feel during the experience of intense physical or psychological pleasure, while eudaimonic happiness is what we feel during experiences in which we reach our personal goals or we perceived to have expressed our potential, our abilities, or to really be who we are.

Prior studies about neural correlates of happiness have focused attention on pleasure experiences, completely ignoring this distinction. None study has investigated the neural basis of these two main aspects, but happiness models were developed thanks to experiments that induced either eudaimonic or hedonic happiness indistinctively.

The aim of this study was to investigate whether distinctive neural patterns correspond to this psychological distinction. To reach this goal I designed an experiment to be performed during functional magnetic resonance imaging (fMRI) scanning.

In the first chapter, an overview of what an emotion is and the various efforts made to define and categorise different emotions specifically is provided. Then, I outline the role of affective neurosciences and the progress made by knowledge in this field. I also describe the basis of neuroimaging: one of the most widely used techniques to investigate neural correlates of emotion.

In the second chapter I attempt to explore the concept of happiness. I present in common terms what happiness is, then I describe the different efforts to define happiness. An overview of different approaches to the study of happiness and its main aspects are provided.

In the third chapter, an overview of the different mood induction procedures often used in affective research is provided. The focus is then pointed on autobiographical recall and its correlates, considering that most fMRI investigations about happiness use autobiographical recall as a mood induction procedure.

The fifth chapter provides a neural basis of the original method used to induce happiness in this research, at the boundaries between envisioning the future, daydreaming and transportation into narratives. I also describe the Brain's Default Network, which seems to be the common network activated during all these cognitive activities.

The sixth chapter presents the research I conducted, in which neural correlates of hedonic and eudaimonic happiness are explored. Participants were guided to experience happiness through the imagination of different “happy” and “neutral” events. In this chapter, experimental design, participants, methods and results are also described.

Finally, in the seventh chapter, discussing results, conclusions, limitations and future research directions are provided.

CHAPTER 1: EMOTIONS

1.1 Introduction

This chapter attempts to describe a framework in which happiness could have significance. Although there is no agreement about the definition of happiness as an emotion and it is often treated as a mood or a complex psychological state, as we will see in subsequent chapters, it is also considered a positive emotion in affective neuroscience. It is thus necessary provide a definition of what precisely an emotion is. In this chapter we will take a look at different definitions and taxonomies of the term “emotion”. We will give a historical overview of the developments in the definition of what an emotion is, trying to find common features. Finally, we will describe neural correlates of emotion in a system called the “emotional brain”.

1.2 Different ways to categorise emotions

In literature on the topic it is hard to find a shared definition of what emotion is. Fehr and Russel (1984) express this difficulty, writing that “everyone knows what an emotion is, until asked to give a definition. Then, it seems, no one knows” (p.464). The concept of emotion, much like the definition of each emotion, varies across countries, culture and history. Generally, it could be defined as a subjective reaction to a salient event, characterised by physiological, behavioural and experiential modifications (Stroufe, 1996), but Kleinginna and Kleinginna (1981) reviewed 100 definitions of emotion found in relevant literature and categorised them into 10 lists, each emphasising different aspect of emotion. We present this list with the emphasised aspects:

1. Affective definitions (focusing on arousal and hedonic value)
2. Cognitive definitions (focusing on appraisal and labeling)
3. External stimuli definitions (focusing on emotion-generating stimuli)
4. Physiological definitions (focusing on internal physical mechanisms)
5. Expressive behaviour definitions (focusing on externally observable responses)

6. Disruptive definitions (focusing on dysfunctional effects of emotion)
7. Adaptive definitions (focusing on functional effects of emotion)
8. Multi-aspect definitions (focusing on interrelated components of emotion)
9. Restrictive definitions (focusing on distinctive characteristics of emotion)
10. Motivational definitions (focusing on relationship between emotion and motivation)

Additionally, the term "emotion" is often used interchangeably with other terms such as mood, passion, sentiment, feeling, affect, attitude, motivation, desire and arousal. Some of these constructs are well-defined, other less so (Sander, 2013). It is thus necessary outline the specificity of emotion.

Within the categorisation of emotion, various types of taxonomy were proposed. The first widely used taxonomy suggests "*basic emotions*" otherwise called "primary", "discrete" or "fundamental". They are usually anger, disgust, fear, enjoyment, sadness and surprise (see Matsumoto & Ekman, 2009) and are considered to be more elementary than others. Following this taxonomy, basic emotions differ one from another in significant ways and as are modeled by evolution they can model non-basic emotions (Ekman, 1992).

Other taxonomies, more pertinent for the current dissertation, distinguish emotions on the basis of their valence: *positive versus negative emotions.* What is used to distinguish emotions' valence is often unclear (see Colombetti, 2005). Sometimes it is the elicited feeling (pleasant or unpleasant), other times it can be the eliciting event. Eliciting events and elicited feelings are not often coherent between each other. Additionally, the evaluation of an event could be uncertain. In affective neuroscience, the categorisation between positive and negative emotions is extensively used and is grounded in various research traditions; for example the tradition of counterpoising a pain/aversion system to a pleasure/reward system (see Haber & Knutson, 2010). The theory of Berridge and Kringelbach (2011), which will be discussed in more depth in the next chapter, shows a limit to the distinction between positive and negative. This theory accounts for a subservient system for *wanting* processes and a subservient system for *liking* processes that are often incongruent between each other. Another incongruence is based on hemispheric distinctions; while some theories specify the right hemisphere as a centre for negative emotion and the left one as a centre for positive emotion (e.g. Ahern & Schwartz, 1979), other theories speculate that the right hemisphere is a general centre for emotions (e.g. Gainotti, 2000). It is necessary to keep these limitations in mind when considering the study of positive emotion versus negative emotion.

Another taxonomy used is one based on the distinction between *approach-related* and *avoidance-related emotions.* Davidson and Irwin (1999) proposed that in the anterior part of the brain there is an asymmetry consisting of a side relating to appetitive behaviour that generates approach emotions to reach a goal, in other words left-lateralised, versus a system in the right hemisphere that generates withdrawal-related emotions. This hypothesis cannot overlap with valence hemispheric asymmetry hypothesis, making for an interesting dissociation between valence and action tendencies (Sander, 2013).

Other categorisations define the presence of some *"self-reflexive emotions"* such as shame, guilt, pride, and suggest that what elicits emotion is the self (Fontaine, 2009). *"Aesthetic emotion"* is a term suggested to describe when the objects able to elicit emotion are artwork or scenes in nature (see Robinson, 2009) while *"make-believe emotions"* are emotions elicited by fiction (perhaps a book or film), when the subject is aware that the eliciting material is not real. This final category of emotions is described as being qualitatively different from genuine emotion and needs to be considered in neuroscience research about emotions, including the research presented in this dissertation, because studied emotions are often elicited by fictional material generated in a laboratory that significantly changes prefrontal cortex responses (e.g. Vrticka, Sander & Vuilleumier, 2011).

A further category *"counterfactual emotions"* are elicited by counterfactual thinking that considers alternatives to reality. These can include for instance regret and disappointment (see Coricelli & Rustichini; 2010; Roese, 1994). *"Social emotions"* are those elicited by social situations (e.g. shame, embarassement, jealousy, guilt and gratitude) (see Hareli & Parkinson, 2009); *"moral emotions"* are elicited by moral evaluations (e.g. shame, guilt, compassion and gratitude) (see Haidt, 2003; Mulligan, 2009; Tangney, Stuewig, & Mashek, 2007); and finally, *"epistemic emotions"* are related to knowledge and learning (e.g interest, confusion and surprise) (Morton, 2010; Silvia, 2010).

All of the categories outlined above are not mutually exclusive, and different taxonomies could be useful for different studies. In any case, it is necessary to consider the point of view given by any taxonomy when one is adopted, and to know the limitations of each (Sander, 2013).

1.3 Models and definitions of emotion: a historical view

In the last century many models have been designed with the study of emotion in mind.

First, James and Lange (1884) suggested that an exciting fact could cause bodily changes and that the perception and the feeling of these changes is what is called an emotion. This is defined as the *peripheral theory* of emotion and assumes the presence of a mechanism that links bodily changes to cognitive interpretation in a retroactive way.

Reacting directly to this theory, Cannon and Bard's model (1928 - 1929) was designed around the hypothesis of a centre for emotion localised in the hypothalamus. This theory is known as the *central theory*. The cortex is involved in the conscious experience, and bodily changes provide the energy to increase emotional responses.

Considering the role assigned to hypothalamus in this model, Papez (1931) proposed the first model of a emotional cerebral circuit. This was done by adding consideration of the hippocampus and cingulate cortex to Broca's definition of a limbic lobe. This model was then defined with contribution from MacLean (1952) and Kluver Bucy (1939) who assigned a role to the amygdala. Thus, they came to a definition of the *limbic system*.

The advent of behaviourism was the fundamental basis in understanding emotional mechanisms, particularly with the study of learning influenced by emotion in human and animals (e.g Watson & Rayner, 1920). In general, behaviourism linked emotion to motivation (reward and punishment).

With the revolution of cognitivism, cognition began to be considered a central aspect of emotion, allowing the development of different models. For instance, in the theory of Schacter & Singer (1962), emotion is the results of two components: arousal and cognitive processes, linked by the interpretation of social and physical context. This interpretation makes the subject able to detect the cause of perceived arousal. (Sander, 2013).

Frijda's model (1988) states that, in a specific situation, emotions arise in response to a meaningful structure.

Finally, a more recent model (Damasio, 1994) integrates what was traditionally considered bodily and what was traditionally considered mental components. Within this view, emotion is defined as the integration between a mental evaluation of the situational environment and the feeling of physical somatic changes. The evolution of thought linked to this model is the equal contribution achived by body and by mind. The model suggests that they work in synergy to evaluate a situation. Not only does the mind read bodily changes, but at the same time, somatic sensations (the *somatic marker*) guide the interpretation.

1.4 Finding a definition of emotion

All definitions of emotion share four key criteria:

1. *Emotions are phenomena composed by multiple processes*:
   An emotional episode is formed by multiple integrated components that include affective, behavioural, cognitive, expressive, autonomic and psychological changes (Fig. 1.1)

Fig. 1.1 Multiple processes involved in emotion

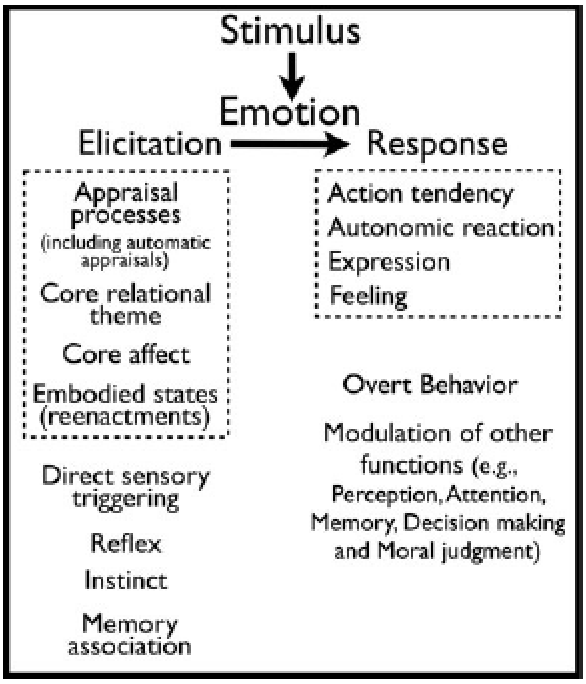


Image from (Sander, 2013)

2. *Emotions involve both mechanisms able to elicit emotion, and an emotional response*: they are two-step processes. Modern models consider the process of emotion elicitation as constitutive of the emotion: this is its first step. Response is the second step. Emotions could be elicited by major determinants: *appraisal dimensions, core*

relational themes (that represent a distinctive type of adaptational relationship to one's circumstances), *core affects* (neuropsychological states that access consciousness, and simple primitive feelings), *embodied states*, *direct sensory triggering* and *reflexes* (automatic emotional reactions to evocative stimuli), *instincts* and *memory associations* (Fig. 1.1).

3. *Emotions have relevant objects*:
   Emotion is elicited by objects considered relevant to the subject. Most theories consider evolutionary significance; others consider major concerns to the individual (goal and satisfactions) (Frijda, 1986); others consider the probability of satisfaction toward major concerns of the individual while other theories consider appraisal that guides judgments about the relevance of a specific object.

4. *Emotions have brief duration*:
   Compared to other affective phenomena they are considered brief episodes with quick onset and end (Sander, 2013).

1.5 The study of emotion in the field of affective neurosciences

In the 1990s a new trend arose in research about emotion. Affective neurosciences improved knowledge about constituents of the emotional brain (e.g. Davidson & Sutton, 1995; Panskepp, 1991). The intent of affective neuroscience is to bridge different approaches and models about emotions and affects (moods, affective dispositions, preferences) developed in an independent way by research in recent centuries. Since the beginning of the twenty first century, electro encephalography (EEG) and magneto encephalography (MEG) have become widely used non-invasive methods which are fruitful in conducting affective research in reason of their temporal resolution, able to keep data about different stages of the emotional process. Studies conducted with EEG and MEG provide large-scale measurements of brain activity, suggesting dynamic cortical networks during affective processing. Advances in technology allow a better understanding of spatiotemporal dynamics and links with subcortical structures.

In the last few decades, neuroimaging techniques, based on the concept that activity in one brain region is accompanied by increases of blood and oxygen in that region, became the most common way to study emotional processes and their neural correlates. The most widely-used techniques are Positron Emission Tomography (PET) and functional Magnetic Resonance (fMRI). Also often used is Single Photon Computed Tomography (SPECT).

PET uses radiotracers, molecules marked with substances able to induce radiation (isotopes).These radiotracers allow external measurement of what happens in the brain. Different molecules in the brain can be traced and, thus, different changes and processes can be measured. When the oxygen in water is marked, PET can measure regional cerebral blood flow (rCBF) as an index of neural activity; given that the principle of neural activity requires oxygen and glucose to be made. Another indicator can be the amount of glucose in a cerebral region. Another else is the activity of different neurotransmitters, tracing them with isotopes (ligands).

fMRI has several advantages relative to PET. Firstly, an increased spatio-temporal resolution and secondly, it does not need radiation. The principle on which fMRI is based is that atomic nuclei have an intrinsic *spin*, meaning that they revolve. This spin has a vector; it follows a direction. Without an external magnetic field, the different spins go in random directions. When an external magnetic field is induced, these spins will assume a specific direction. Signal generation in fMRI scanning is based on this concept. Electromagnetic energy, generated by the machine, is absorbed by the atomic nuclei. In fMRI conducted on living beings, electromagnetic impulses are matched with hydrogen nuclei frequencies. Once absorbed, the electromagnetic energy is released. The amount of energy released depends on the amount of hydrogen nuclei present, on the magnetic interaction with other nuclei and with the molecular environment. Hence, different tissues produce different signals: that allows to produce an image in which different tissue is represented by differing shades of grey.

fMRI scanning in the brain is based on the idea that activity in specific brain regions requires oxygenated blood. Considering that the magnetic properties of blood are strongly different when it contains or does not contain oxygen, this principle was used to view in vivo activities, through the measurement of blood-oxygenation-level dependent (BOLD) contrasts.

During fMRI scanning, each voxel (a three dimensional quantum of space in the brain) is analysed independently, and then massively computed using the general linear model (GLM). Following, the estimated parameter is taken to a second-level analysis: generally a t-test or ANOVA that contrasts the conditions of interest.

fMRI experiments require the contrast between one or more conditions, and control these conditions based on the principle of subtraction. Subtractive methods try to isolate brain regions related to one activity by contrasting two similar tasks that differ only in the target activity. An alternative method is the parametric one that considers a factor of interest varied along a scale, which is then analysed, with performing regression analyses then undergone. (Armony & Han, 2013; Sacco, 2013)

1.6 The emotional brain

When discussing emotion we do not refer to isolated brain areas but to interconnected brain areas which converge in neural networks. A structure that allows rapid emotional evaluations is the amygdala, in the medial temporal lobe, close to the anterior part of hippocampus. The amygdala is fundamental to learning and memory for emotional stimuli (Pessoa, 2008; LeDoux, 1996). It is involved in different neural processes: from conditioning to fear, but also in response to positive stimuli as it reinforces learning. It is a store of emotional memory: recording and triggering fast emotional reactions.

The amygdala is divided into three parts: the basolateral region which has extensive connections with the human cortex; the corticomedial nuclei which have connections with the olfactory bulb and olfactory cortex; the central nuclei, connected with brainsteam, hypothalamus and that coordinates visceral reactions. The amygdala receives innervations from sensorial cortices and the insular cortex (a region that processes visceral information) and from thalamic nuclei. With its innervations, the amygdala influences the activity of the visceral nervous system (Passer et al., 2013).

The amygdala does not work alone, but in concordance with many other structures in the brain. Already cited, the hypothalamus regulates brain activity trough complex hormonal activity regulating different functions of the organism. Sensory cortices are also interconnected structures, but the prefrontal cortex (PFC) is also a principal component of the emotional brain, and is deeply connected to the amygdala. In this region, a conscious evaluation of the stimulus is made and a behavioural reaction is planned, in order to realise a contextual adapted reaction. PFC is divided in dorsolateral (dlPFC) and ventromedial (vmPFC) regions. The dlPFC seems to be more involved in the capacity of maintaining information in the working memory, while the vmPFC is more strongly interconnected with the amygdala. vmPFC also involves the orbitofrontal cortex (OFC) and cingulate cortex. The OFC regulates emotional states; it is a convergence hub for sensorial information, emotional reactions and cognitive processes (Kringelbach, 2005). It is also strongly involved in pleasure evaluation as will be discussed in following chapters, and makes cognitive evaluation of the pleasure that a stimulus could give, thus guiding behaviour.

The Anterior Cingulate Cortex (ACC) is another key hub of the emotional brain. In the PFC, it is strongly connected with parietal motor regions and is a centre of the bottom-up and top-down exchange of information. Its inferior part is connected to the amygdala, hypothalamus, insula and nucleus accumbens (nACC). It is involved in the evaluation of the salience of emotional stimuli and their association with needs and motivations; it is also responsible for the detection of errors and behaviour monitoring. Furthermore, it is the region in which danger and troubled feelings are subconsciously elaborated.

Finally, the insula is a region situated within the temporal and frontal lobes. It controls visceral sensations and detects pain, and it is involved in drug addiction and the processing of social emotions.

Other regions that need to be taken into account are the basal ganglia, responsible for repetitive behaviours, reward and focusing attention and that are tightly connected with motor cortex, and the ventral tegmental area (VTA), involved in the dopamine pathways of a reward system that will be explored when discussing pleasure (Bear, Connors & Paradiso 1999; Dalgleish, 2004; Passer et al., 2013). See Fig. 1.2 for locations of emotional structures within the brain.

Fig. 1.2 Main structures of the emotional brain

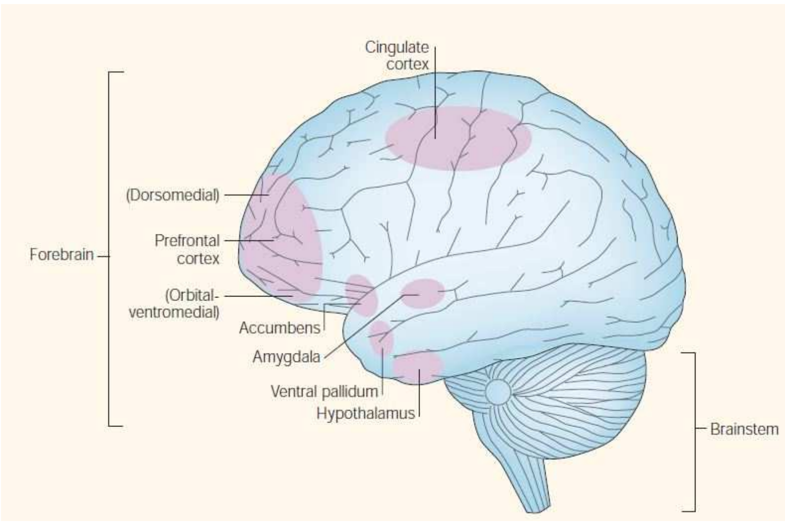


Image from (Dalgleish, 2004)

This system has proved to develop continuously in the first two decades of life: this is particularly true for bidirectional connections between the amygdala and PFC; the PFC undergoes a reduction in gray matter and thickness, while the amygdala increases volume during childhood and adolescence. White matter continues to increase, reflecting axonal myelination and the augmented efficiency of transmission between areas of the emotional brain (St. Jacques, Winecoff, & Cabeza, 2013).

CHAPTER 2: THE STUDY OF THE CONCEPT OF HAPPINESS AND ITS CORRELATES

2.1 Introduction

Happiness is the most prevalent target in everyone's life. The pursuit of happiness should be the first activity in which people are engaged. Everyone knows what happiness is, but few persons are able to define it and fewer still agree about just what it is.

Many sciences and disciplines, including but not limited to psychology, economy, sociology and genetics have tried to define it.

In this chapter we present the ways in which language and culture can influence the idea of happiness and how different sciences have studied this concept, underlining the difficulty in finding an agreed definition. We will then focus on the psychological study of happiness which defines two principal aspects of this emotion (eudaimonic and hedonic), highlighting what neuroscience has discovered about it.

2.2 How language can model the concept of happiness

The term happiness is often used in an interchangeable manner with other similar terms like *well-being*, *flourishing*, *optimal functioning*, *life satisfaction*, *quality of life* and *health* (Chemali, Chahine, & Naassan, 2008; David, Boniwell, & Conley Ayers, 2013; Diener, Lucas, & Oishi, 2002; Easterlin, 2010; Kahneman, Diener, & Schwarz, 1999; Keyes & Haidt, 2003; Layard, 2006; Lykken, 1999; Seligman, 2011; Veenhoven, 2000).

Studies on the English language demonstrate that the term "happiness" seems to be the most peculiar example of emotion, including changes of cognitive, physiological or the behavioural kind, happening together in response to a stimulus, including a level of arousal and a perception of valence distinctive for each subject. It is notable that the term "happiness", in more than one tongue, (i.e., Latin, Italian, English, German) is closely linked to luck or generally to what has to happen: in old English “good hap” had the meaning of “good luck”.

In countries further from Europe, we can find terms related to the concept of happiness that differ from the original meaning: for example in some rural regions of Ghana the term “*anigye*” is used to mean happiness, and could be translated as “gain the eye”, meaning the changes people see in the eye of a happy individual. Another used term is “*suhipelli*” that literally means “white heart”, describing what metaphorically happens in the heart of happy people. Both concepts are related to somatic changes that follow happiness (Sotgiu, 2013).

2.3 How culture can model the concept of happiness

It is generally agreed that culture, habits, and values are able to model the concept of happiness (Delle fave, Bassi, 2009; Diener & Suh, 2000;Uchida & Kitayama, 2009; Uchida, Norasakkunkit & Kitayama, 2004). Consequently, these models can influence the kind of happiness experienced by people from differing cultures. This is the reason for which the study of the concept of happiness, has adopted a transcultural approach in recent decades. A study conducted by Lu and Gilmour (2004) analysed the concept of happiness in two different cultures; American and Chinese. The study involved asking people to give a written definition of happiness. People from both countries defined happiness as the state of mind of deep satisfaction and gratification, coming from positive evaluation of personal present life conditions and from optimistic way of thinking to the future, made by the subject. Happiness was also defined often as the absence of pain, unhappiness, depression and loneliness. However, while American participants described happiness entirely dependent from personal effort, on the contrary Chinese subjects put more significance on the reaching of happiness to the people around them, social context and destiny, considering happiness to be a spiritual balance within the inner being of each person and between his social relations. Chinese and American core themes when discussing happiness reflect the typology of society: they express the extremes of the continuum from individualism to collectivism.

Pflug (2009) compared people from Germany and South Africa, showing that in both countries happiness was considered a state of satisfaction that comes from positive affective experiences which have occured within personal social relationships. Yet while German participants gave more importance to hedonic experiences, South African participants gave importance to experiences of internal peace and quiet. Interesting is that at the time in which the research was conducted, Germany was in the middle of an economic crisis, while South Africa had good perspective of development.

Other studies analysed the different naive concepts of happiness in different countries (Chiasson, Dubè, & Blondin, 1996; Galati, Manzano, & Sotgiu, 2006; Pflug, 2009; Uchida & Kitayama, 2009) showing how they share some themes, turning around the development of personal resources or pursuit of pleasure, but they present some peculiarities. These peculiarities are linked to the type of countries and culture, or to the historical moment, the kind of society and the level of economic development in the country where the studies were conducted, affecting values and priorities essential to reach happiness (social relations, friendship, health, job, etc.).

2.4 Happiness or pleasure? The contribution of philosophy

Philosophers have tried to define happiness and its pursuit since ancient times.

Since the beginning of this debate, two streams arose. In the first, happiness is seen as development of the virtues of human beings; while the second view considers happiness to be the same as pleasure. These streams arose in the ancient Greek and Roman culture and they have continued to be counterposed up until modern times.

The first tendency, considering happiness as developing virtues, was developed from Aristotle in the Nicomachean Ethics, a book outlining the basics of western culture. Aristotle defines happiness as the highest good and he says that the main road to living happily is to act and behave righteously and to follow virtues. Virtues are categorised as moral or intellectual virtues. Moral virtues are the “golden mean”: a desirable medium between two extremes of deficiency and excess. They represent how the irrational part of the soul can obey to reason; the distinctive characteristic of human beings. Moral virtues include bravery, temperance, liberality, magnificence, magnanimity, proper ambition, patience, truthfulness, wittiness, friendliness, modesty and righteous indignation. Thus, the happy individual is the one able to live regulating his behaviour and his emotions, equally distanced from the opposed extremes. Intellectual virtues belong to the rational part of the soul; they are scientific knowledge, art, wisdom, intuition and prudence. According to Aristotle, intellectual virtues are higher than moral ones and they are the main road to gain the perfect happiness: contemplative reasoning. Happiness is an art that anyone can learn, improving personal virtues and deeds. The intellectual virtues help us to know what is admirable and right, and the moral virtues help us to act in a right and admirable way. Aristotle also provides a definition of pleasure, saying is not bad when sought with moderation, otherwise it becomes a vice: an extreme emotional or behavioural habit that denotes lack of self-control and causes unhappiness.

In Stoicism, whose principal philosophers were Seneca and Epitteto, happiness remains the same as virtue, but real virtue was considered the ability to face enemies of personal interior balance in an impassive way. The happy individual is calm, responsible and inflexible; able to be satisfied with little.

The Cyrenaic school of Philosophy, with his founder Aristippus, defined happiness as pleasure. A life could be defined as happy when the person tries to reach the satisfaction of material needs that cause pleasure, avoiding becoming enslaved to them.

Finally, in Epicurus' line of thought, pleasure was the fundamental good. Pleasure could come from the satisfaction of physical needs but not only from them. Pleasure was also the result of conducting oneself or behaving following reason, and its final target was the avoidance of physical and psychological pain.

Two principal inclinations came from these philosophical tendencies: Eudaimonism and Hedonism. Eudaimonism is directly linked with Aristotle's school of thought and it was followed from western Christian ethics and philosophers, like Agostino (354- 430) or Tommaso d'Aquino (1225- 1274); the only difference with Aristotle's thought was that they believed real happiness was reachable only in the afterlife with God's contemplation; this was possible when the individual lived rightly in a virtuous and Christian way (Sotgiu, 2013).

Hedonism spread mostly in the modern age: happiness and pleasure became a target of society regarding which people would be engaged in schools of thought of Cesare Beccaria (1738-1794), Jeremy Bentham (1748-1832) and John Stuart Mill (1806-1873).

2.5 Psychology and happiness

Studies on the neural basis of happiness (see Phan, Wager, Taylor, & Liberzon, 2002, 2004; Murphy, Nimmo-Smith, & Lawrence, 2003; Vytal & Hamann, 2010 for reviews) typically treat happiness as an emotion and not as a highly complex psychological state involving cognitive, affective, and socio-cultural dimensions.

Psychological research has often directed its focus on how to be happy, relying on the basis that everyone has their own definition of happiness. These studies detailed which experiences make one happy (Van Boven & Gilovich, 2003) which characteristics are common in happy people (Diener, 1984) and which psychological needs must be satisfied in order to be happy (Ryan & Deci, 2000). Other researchers focused on the outcomes of happiness, such as creativity, optimism, social reputation and health (Diener & Fujita, 1995; Isen, Daubman & Nowicki, 1987; Campbell, 1981; Richman et al., 2005). Psychologists have tried also to define the components of happiness, but it has always been difficult. Through the years, many concepts have been used concurrently to refer to this (well-being, positive emotionality, life satisfaction, etc.) by different researchers. Haybron (2000) suggests that this is a result of the difficulty to find a shared definition.

Psychological debate on this topic arose officially in the late eighties and is still developing thanks to Positive Psychology, a trend which began in 2000 following the publication of an article by Seligman and Csikszentmihali (2000), considered to be the manifesto of this stream. The cited authors recognised an insufficient effort made by Humanistic Psychology of Maslow (1968) and Rogers (1961) and proposed continuing the study of the human being and its brain, leaving the analysis of sufferance and mental illness in favour of a deeper understanding of human resources, of psychological and behavioural processes and of environmental, social and cultural contexts in order to be able to enhance psychological well-being and mental health.

2.5.1 Two psychological models of happiness

Provided here are two examples of psychological well-known models that were developed in an effort to better understand characteristics, consequences and mechanisms related to happiness.

2.5.1.1 The Broaden-and-build theory

The broaden-and-build theory (Friedrikson, 1998) integrates emotion theory into a well-being framework, accounting for the unique effects of positive emotions respect to other emotions. In this framework, positive emotions appear to encourage expansive thoughts and actions. Two are the effects of positive emotions: the broaden effect and the build effect.

The broaden effect accounts for non-specific cognitive changes. These changes cause behavioural effects. The first impact is on attention. A positive emotion makes the attentional focus wider and larger, in order to include more features of the surroundings. A large set of experiments demonstrated expansive attention and receptivity associating to happiness; the global versus the holistic perception of stimuli and better executive functions together with lower reaction times in classical tasks, as longer fixations to peripheral aspects of images (Fredrickson & Branigan, 2005; Johnson, Waugh, & Fredrickson, 2010; Rowe, Hirsh, & Anderson, 2007; Wadlinger & Isaacowitz, 2006). Other broaden effects arise in cognition, increasing flexibility, creativity and the generation of innovative problem solving (Ashby, Isen, & Turken, 1999; Isen, Daubman, & Nowicki, 1987). Finally, positive emotions can show broaden effects on social cognition, changing the way in which we consider ourselves in relation to others (Aron, Aron, & Smollen, 1992; Waugh & Fredrickson, 2006). This effect, called self-expansion, refers to the ability to find similarities between people and to find overlapping with the personal characteristics of others (Conway, Tugade, Catalino, & Fredrickson, 2013).

The build effect refers to the accumulation of long-term psychological, physiological and social resources consequential to the broaden effect (Conway, McDonough, & Sameroff, 2002; Conway, McDonough, Clark, & Smith, 2001). Experiments were conducted principally with children exposed to maternal positive effects, showing increases in long-term attentional, cognitive and social resources. Increases in well-being, mental health and resilience to significant loss, to hardship and to adversity in life were all build effects noted in adults in terms of the use of effective coping strategies (Fredrickson, Cohn, Coffey, Pek, & Finkel, 2008; Keyes, 2007).

Neural investigations demonstrated that broadened thinking and decision making are modulated by the activations of the nucleus accumbens (nACC), which modulates gain-seeking behaviour and OFC whose role is to evaluate reward and expected outcomes (Rolls & Grabenhorst, 2008). Information given from the OFC to the ACC contributes to the learning of broaden-built actions, with the help of basal ganglia circuitries (Conway et al., 2013).

2.5.1.2 The endowment-contrast model

Another psychological model in the study of positive emotions and happiness is represented by the endowment-contrast model (Tversky & Griffin, 1991). This model was aimed more at giving measures of happiness and well-being, providing a point of view about what could be considered happy events. The model states that the quality of a past event affects the future and the present through a direct effect, called *endowment*, and through an indirect effect, called *contrast* that accounts for comparison between the effects of other similar events, influencing the evaluation of reference standards. These standards are influenced by the novelty, the salience and the intensity of prior events. Consideration of endowment and contrast gives a level of satisfaction, implying that similar events become less satisfying time after time when put in contrast to stored events. The crucial point of this model is the emphasis put on personal history in the judgment of pleasure, happiness and wellbeing (Griffin & Gonzalez, 2013).

2.5.2 Different approaches to conceptualise happines

Theoretical debate in psychology was strongly influenced by philosophical debate and it proposes two counterposed concepts of happiness: eudaimonic and hedonic concepts. This distinction is very useful and allows psychologists to categorise concepts of happiness, even if recently, some researchers have discussed the eudaimonic/hedonic distinction. In particular, Kashdan, Biswas-Diener & King (2008) argue that this distinction between two different kind of happiness does not give any advantage in scientific research, but in fact gives the risk of misunderstandings when the abstract concepts are not clearly operationalised and researchers do not agree on them. They suggest putting the focus on the contacts between these two concepts because they work together within any individual to make a life happy. Huta & Waterman (2014), reviewing the literature, also point out how vaguely eudaimonia and hedonia are often defined by researchers and how they are often used to refer to different concepts, claiming the need to operationalise and define them. They propose that any researcher studying happiness has to declare degree of centrality (core, close-to-core or major correlates), a category of analysis (orientations, behaviours, experiences or functioning) and a level of measurement (stait or trait) when the two terms are used.

Henderson, Kinght & Richardson (2013) proposed a questionnaire based on the Hedonic and Eudaimonic Motives for Activities (HEMA) scale (Huta & Ryan, 2010) to 105 participants. This questionnaire asked participants to rate different activities, judging whether each of them is of hedonic or eudaimonic type. This investigation showed how consider activities pure hedonic or pure eudemonic is not valid, because most of the activity was shown to be at the same time both hedonic and eudaimonic, by a different percentage.

In any case, to continue this dissertation it is necessary to describe the models created to define these two kinds of happiness.

2.5.2.1 Eudaimonic happiness

Alan Waterman (1990, 1993), elaborating his theoretical model inspired directly by Aristotle's thinking, considers human virtue the best way to reach happiness. To be more precise, he proposes the substitution of the term "eudaimonia" with "personal expressiveness" indicating effects such as: states of mind and subjective feelings that the individual can feel when he is engaged in activities able to elicit his skills and abilities able to contribute to reach his personal ambitions and life goals. During the execution of these activities, the subject must be deeply involved in them; he must feel a psychological fusion with the activity and feel vitality and satisfaction thanks to them, as the feeling of being truly what or who he is. This concept is closely linked to the concept of "flow experience" described by Csikszentmihalyi (1975, 1988, 1997). The subject feels so completely absorbed by the activity he is engaged in that he considers it very gratifying and exciting, and his attention is totally focused on it.

In his 1993 study, Waterman found empirical proof of correlation between the two constructs, demonstrating also how feelings of personal expressiveness were strongly related to the degree of concentration.

Ryan, Huta & Deci (2006) kept the term “eudaimonia”, indicating a virtuous lifestyle that leads individual to reach towards their life goals and a good adaptation into his situation that corresponds to what is intended with the expression “living well”. They made the distinction between intrinsic and extrinsic goals and values. They theorised that living well is possible when the individual goals pursued are able to satisfy basic psychological needs as they are autonomous in managing one’s own life, with expertise operating on their own context and on their own social relations; establishing links with other people. For the cited academics, it is more likely that a person satisfies these needs when their personal goals are intrinsic goals that are able to resolve personal and not only material or third-party’s desires. To live an eudaimonic life, the way is mindfulness, considering the ability to pay attention intentionally to what happens in the individual’s life in every single instant.

In the trend of eudaimonic happiness we also find Carol Ryff (1989, 1995; Ryff & Singer, 2008) who defined six constituent of happiness that are as follows: i) self-acceptance, ii) positive relations with other, iii) sense of autonomy in thought and action, iv) ability to manage complex environments in order to suit personal needs and values, v) pursuit of meaningful goals and sense of purpose in life, vi) continued growth and development as a person.

Both Waterman’s and Ryan & colleagues’ models emphasise what is necessary to live in the eudaimonic way. Inversely, Ryff’s model defines six indicators to determine eudaimonc happiness.

The three cited models share the idea of self-fulfillment: the idea that the chance to live a happy life is almost completely dependent on the individual’s choices and actions. This idea is typical of individualistic culture as western culture often is (Sotgiu, 2013).

2.5.2.2 Hedonic happiness

As stated by Ryan and Deci (2001), it is quite difficult to find in psychological literature theoretical models about happiness as a pursuit of pleasure. Two reasons can explain this. First of all, psychological literature, as mentioned above, tends to focus its attention on pain and illness. Secondly, pleasure was always and still remains considered negatively in western society: hedonic life style is still considered morally negative by most people.

However some authors express theory regarding hedonic happiness. Ed Diener and colleagues (Diener, Oishi, & Lucas, 2003) tried to convey the idea that a happy life is when the individual, making an evaluation of his life, can make a positive balance of the total hedonic experiences; in other words a happy individual is the one who has lived more pleasurable experiences than unpleasurable ones.

Brickman and Campbell (1971) defined happiness as a subjective experience of pleasure; a transient state of mind. Feelings of pleasure are intense, but they vanish very fast, and after them the subject comes back to a neutral affective state. Inspired by perceptual theories, they affirm that individuals adapt themselves to emotive experiences. This adaptation always makes the individual always unsatisfied, looking continuously for greater stimulation. Brickman and Campbell defined this condition as the "hedonic treadmill".

Diener, Lucas and Scollon (2006) commented on this definition, disapproving of the idea that everyday life is characterised mostly by a neutral affective state. In fact, the affective state of most of people is not neutral but tends to be positive; when feelings vanish after an affective stimulation, the affective state will return to the state present before. Furthermore, this basic state depends greatly on individual characteristics of personality, optimistic or pessimistic orientation to life and coping strategies. They finally claimed that specific events in life can modulate, even for a long period of time, the basic affective state (Sotgiu, 2013).

2.6 The neuroscience of happiness

The field of the neurobiology of positive emotions has blossomed in the last few decades, after the diffusion of neuroimaging techniques. Data from recent review studies (Phan et al., 2002; 2004), based on the meta-analysis of studies regarding different emotions, demonstrates that some discrete brain regions are involved in specific emotions, while other regions are generally involved in emotion perception, valuation or regulation, without finding specific activations related to specific emotion.

The most cited areas involved in the emotion network seem to be the amygdala, insula, cingulate cortex and medial prefrontal cortex (mPFC). Specifically, the authors argued that the amygdala has a specific role in fear. Sadness activates subcallosal cingulate and mPFC has a general role in coding emotion. Regarding happiness, they claim that many of the reviewed studies reported activations in basal ganglia, including ventral striatum (VS) and putamen, suggesting a role in the response to incentive reward motivation and in “pregoal attainment of positive affect arising from progression toward a desired goal, consistent with the notion that happiness can be conceptualised as an approach emotion” (p. 337, Phan et al., 2002). They also found different activations regarding the task were used to induce emotion: visual stimuli activate more the occipital cortex and amygdala, emotional recall and imagery as an emotional task with cognitive demand activate more the ACC and insula, suggesting a different role played by each different area in processing an emotion.

In regard to happiness, research focused mostly on pleasure. It is easier to recognise, define and study, even in the brain of other mammals like rats given the similarity with human brain, and indicates how the pleasure system is deep in the brain and how philogenetically deep-rooted is (Berridge & Kringelbach, 2011). These results suggest an adaptive function of pleasure relating to survival. Studying happiness, the focus on pleasure was justified by the assumption, coming from behavioural studies, that pleasure in life often coexists with meaning in life: most happy people rate their life meaningful as much as they rate it full of pleasure (Diener, Kesebir, & Lucas, 2008; Kuppens, Realo, & Diener, 2008). Even if conceptually the two aspects are very different, they strongly correlate: happy people feel much pleasure and pleasure can considered essential for wellbeing. On the other side, the pathological loss of pleasure (i.e. anhedonia) typically impedes happiness and wellbeing (Gorwood, 2008).

With these assumptions, the hedonic concept of happiness has been the most studied and discussed in the field of neuroscience, and much is known about brain mechanisms of pleasure. Basic sensory pleasures (food, sex, drugs, etc.) are the most studied because they are easier to study, but some evidence demonstrates the overlapping of these mechanisms with those of higher order pleasures (artistic, intellectual, musical, etc.) (Frijda, 2010; Harris et al., 2009; Leknes & Tracey, 2008, 2010; Salimpoor, Benovoy, Larcher, Dagher, & Zatorre, 2011; Skov, 2010; Vuust &

Kringelbach, 2010). For the same reason, it appears reasonable that mechanisms of pleasure can contribute to, and be in part shared with, mechanisms of high order happiness.

2.6.1 Neuroscience of pleasure

When the focus is on the experience of a pleasant stimulus, the neurobiological mechanisms of pleasure include at least three components: wanting, liking and learning. Each of these components is further broken down in a conscious and a non-conscious side (Fig. 2.1) (Kringelbach & Berridge, 2009), both in the motivation to reach for something and in the enjoyment of a pleasure (Gruber & Moskovitz, 2014).

Wanting is the motivation to gain a reward, *liking* is its enjoyment, while *learning* includes predictions about future rewards.

The conscious sides of these three aspects are divided as follows. Liking is the conscious, known experience of pleasure, wanting is the desire to gain a goal which pleases in some way, and learning includes conscious increases in knowledge and predictions. On the non-conscious side, liking corresponds to the activity in the systems related to the hedonic value, wanting is represented by motivational processes and incentive salience, while learning includes implicit knowledge and associative conditioning. All of these non-conscious aspects correspond to behavioural or neural measures.

Fig. 2.1 Measures of reward, pleasure and examples of related brain circuitry and neutransmitters involved (NAc =nucleus accumbens, Ach= acetylcholine, VP= ventral pallidum)

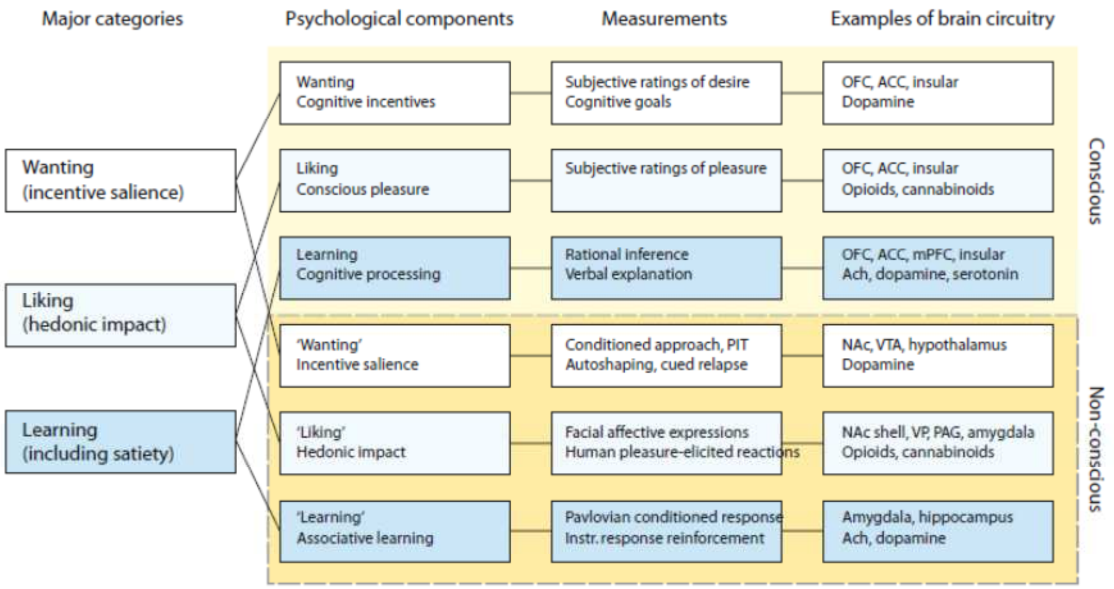


Image by (Berridge & Kringelbach, 2011, p. 5)

Considering the aspect of non-conscious liking, neural circuits are scattered in the brain but evidential proof was found only for some locations deep in the brain, called "hedonic hotspots".

The similarity between pleasure reactions in many mammals, which are like facial expressions in response to pleasant or disgusting stimuli in humans, permits the belief that brain mechanisms implied in them are similar.

Studying rodents, a hotspot is found when a pleasure reaction is elicited using a stimulating opioid, endocannabinoid or other hedonic neurochemical receptor. Researchers found the boundaries of these hotsposts by measuring when the same stimulation does not elicite any response (Mahler, Smith & Berridge, 2007; Pecina & Berridge, 2005; Pecina, Smith & Berridge 2006; Smith & Berridge, 2007).

These studies defined a network of different hedonic hotspots. Activating one employs the others as a system, and more activated hedonic hotspots means more hedonic liking (Pecina, 2008; Pecina & Smith, 2010; Smith, Berridge & Aldridge, 2011; Smith, Mahler, Pecina, & Berridge, 2010). These circuits are different from those that mediate other pleasures' features.

One hotspot is the nACC, specifically its medial region. Another of these regions is the VP, which receives outputs from the nACC. Other hotspots were found in limbic regions of PFC, and in the parabrachial nucleus, at the top of the pons (Berridge & Kringhelbach, 2011;Chemali et al., 2008; Funahashi, 2011; Gruber & Moskovitz, 2014; Kringhelbach & Berridge, 2009). Only some of these locations are truly necessary to elicit pleasure: this is the case of the VP. Lesions of the VP in rodents demonstrate the ability to transform liking into disgust or disliking (Berridge et al., 2010; Cromwell and Berridge, 1993; Smith et al., 2010). A case study of a human with selective lesions of the VP after a drug overdose demonstrated that personal feelings in this patient were dominated by depression, guilt and anhedonia. It seems that the VP is a core region that receives outputs from the nACC and PFC, and transmits signals to the PFC via the thalamus (Smith et al., 2010). Also the amygdala (Chemali et al. 2008; Fernando, Murray, & Milton, 2013; Mahler & Berridge, 2012) was discovered to code for pleasure much like the PFC. Pleasure is coded especially by the OFC, ACC and mid-insular cortex (Aldridge & Berridge, 2010; Grabenhorst & Rolls, 2011; Kringelbach, 2010; Leknes & Tracey, 2010; Lundy, 2008; Salimpoor et al., 2011; Skov, 2010; Tindell, Smith, Pecina, & Berridge, 2006; Veldhuizen, Rudenga & Small, 2010; Vuust & Kringelbach, 2010). It is worthy of note that many of these sites code for pleasure, meaning that their activity could reflect causation but also a consequence of pleasure. It is more difficult to find which of them only causes pleasure. Causation is inferred by measuring changes in pleasure that manipulate brain activity (Berridge & Kringelbach, 2011).

A region of the brain was found in humans whose activity correlates strongly with subjective pleasantness: this was the mid-anterior zone of the OFC (Kringelbach, 2005); mostly activated anteriorly from abstract reinforcements than from concrete ones. Another site is found along the medial edge of the OFC and seems to code positive valence. Its activity is contrasted with activity in the lateral orbitofrontal areas that code for unpleasant stimuli. It is still uncertain whether these frontal regions can cause pleasure. Data from lobotomised patients does not indicate a total loss of pleasure. (Damasio, 1999). On the contrary, in some cases patients showed euphoria, impulsiveness and general disinhibition (Hornak et al., 2003); Beer, Heerey, Keltner, Scabini & Knight (2003) demonstrated the permanence of good humor and self-satisfaction in patients with orbitofrontal damage. This data suggest that the OFC could be more important in transforming pleasure stimuli into their cognitive representations (Burke, Miller & Schoenbaum, 2010; Dickinson & Balleine, 2010).

Other sites were once considered to be able to cause pleasure, This is the case of the mesolimbic dopaminergic system (Wise, 1985). The *dopaminergic system* (Fig. 2.2) is a network of areas in which a release of dopamine during the feeling of positive emotions was hypothesised (Ashby, Isen, & Turken, 1999). This system is formed by two pathways; the nigrostriatal pathway, which begins in the substantia nigra that releases dopamine to the VS and is responsible for increased motor activity after positive emotions, and mesocorticolimbic pathway, which begins in the ventro-tegmental area (VTA) and releases dopamine to the locus coeruleus, olfactory cortex, hippocampus, amygdala, PFC and ACC. The latter is responsible for the effect of positive emotion to memory (Mammarella, 2011).

Fig. 2.2 Dopaminergic pathways and reward system

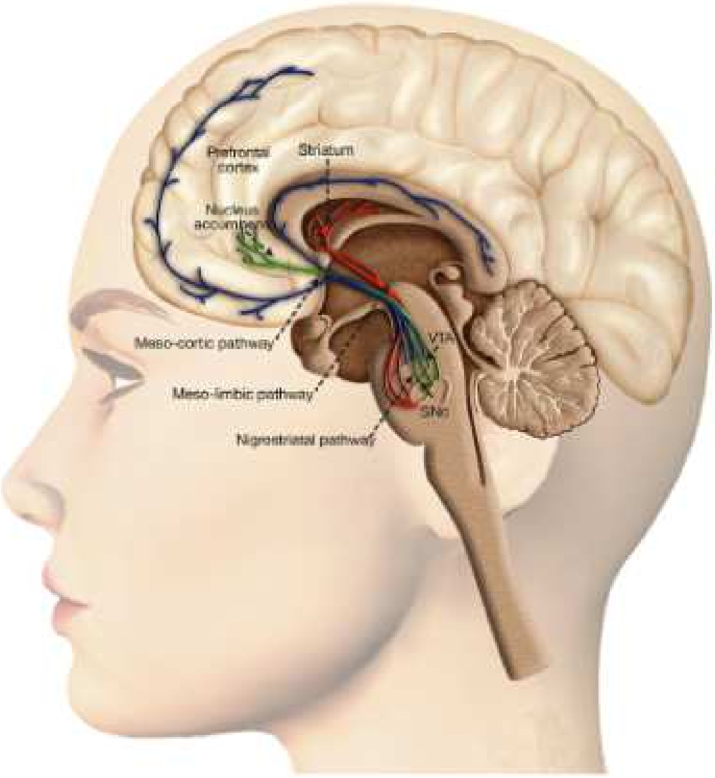


Image by (Arias-Carriòn et al., 2015)

It is now mostly agreed amongst neuroscientists that these sites code for predictive and motivational properties, rather than for hedonic ones. It seems that this system is crucial for the wanting aspect of pleasures (Redgrave & Gurney, 2006; Salamone, Correa, Farrar, & Mingote, 2007; Schultz, Dayan, & Montague, 1997) and when stimulated in rats, increased seeking of rewards, yet not always increased the liking of these rewards.

The classic work of Olds and Milner (1954), in which a rat presses a lever to stimulate brain electrodes in structures of this dopamine mesolimbic system, and continuously presses it to have more stimulations, seemed to demonstrate the pleasantness evoked from the activation of these regions. Recent studies demonstrated that when these areas are externally activated by electrodes, they make the rats more motivated for food, sex, drinking, but they fail to increase the rats liking of these rewards (Berridge & Valenstein, 1991).

Also in humans, data demonstrating the causation of liking during the activation of these sites is not strong. Studies always report an increase in seeking such stimuli such as sex, food, drugs, but electrodes' stimulation of these regions was never clearly associated with a persistent feeling of pleasure (Berridge & Kringelbach, 2011; Heat, 1972; Portenoy et al., 1986). On the contrary, in some cases subjects reported an annoying and finally unpleasant sensation coming from these stimulations and their consequences. For example, this was true in the case of mirth and laughter, generated by the Deep Brain Stimulation of the subthalamic nucleus in Parkinson's disease patients (Krack et al, 2001; Schlaepfer et al., 2008). It is also what happens to the drug-addicted sensitisation of the mesolimbic system; when its over-activation induces hyper-reactivity to incentives, even when enjoyment is not simultaneously experienced (Berridge & Kringelbach, 2011).

2.6.3 Neuroscience of eudaimonic happiness

It is difficult to find studies which deal directly with the neuroscience of happiness in its eudaimonic aspect. Most studies on happiness did not contemplate both sides of happiness, and generally based the definition of happiness on what each participant considered to be a happy thing, or otherwise focused on correlates of happiness, like laughter and mirth (e.g. Chemali et al., 2008). In some cases they treated happiness only in its hedonic aspect, or focused mostly on it in some way. At the moment only some hypotheses were made by researchers focusing on eudaimonic happiness. Berridge and Kringelbach (2011; see also Kringelbach Berridge, 2009) tried to bridge pleasure to meaning, hypothesising a neuroscience of eudaimonic happiness without empirical proof. In their review, they highlight the overlapping of hedonic hotspots (OFC, nACC and VP) with what is called the Brain's Default Network (BDN): a steady state circuit that is perturbed when the subject is engaged in a cognitive task, proposed in recent literature as the locus of self-representation and states of consciousness (Buckner, Andrews-Hanna, & Schacter, 2008; Gusnard & Raichle, 2001; Lou et al., 1999). BDN will be described in more depth in chapter 4.

Following Berridge and Kringelbach's thought, this system, and particularly the areas shared with hedonic hotspots network, might be important for higher pleasures and eudaimonic happiness. This could be true at least for the frontal key regions (the ACC and OFC) that are dense with opiate receptors (Henriksen & Willoch, 2008).

Other regions were proposed as candidates as coding for well-being and eudaimonc evaluations of the self. This is the case of the dorsolateral prefrontal (dlPFC) and other parietal and temporal cortex networks (Heller et al., 2009). How these systems work together is still unclear.

Fig. 2.3 Hedonic circuitries in the brain of rodents and human.

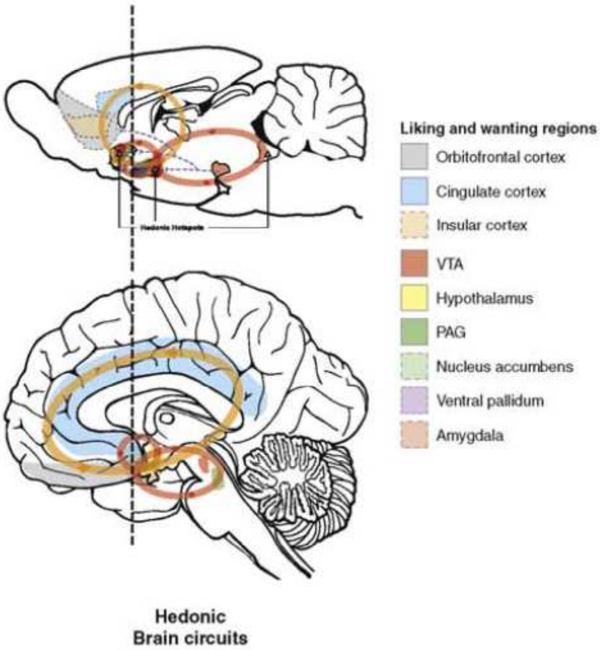


Image by (Kringelbach & Berridge, 2009, p. 482)

2.6.4 Pathological lack of happiness

The comprehension of pathological states caused by loss of pleasure and happiness as the knowledge of their neural correlates could help in understanding mechanisms of happiness. In this paragraph we will discuss anxiety and mood disorders.

2.6.4.1 Anxiety disorders

People affected by anxiety disorders (post-traumatic stress disorder, social anxiety disorder and generalised anxiety disorder) devote substantial time in avoiding contact with anxious thoughts and bodily sensations as default coping strategy. This mechanism diminishes contact with present experiences and also progresses towards personal goals, through the reduction of the ability to evaluate and extract reward from what they live. Conversely, people with anxiety disorders consider noxious, dangerous and fearful stimuli (whether familiar or novel) in absence of a real danger in the context. It seems that this change in reward evaluation is due to an over-activation of fear responses and the generalisation of fear. The brain structures involved in anxiety disorders are the ACC, hippocampus, insula, amygdala and vmPFC (see Kindt, 2014 for a review). The response of the amygdala to emotional stimuli is particularly disrupted. Through basocortical nuclei, information comes to the central nuclei that activate stress responses causing a release of cortisol. In normal conditions, the hippocampus inhibits cortisol production, but a prolonged exposure to cortisol causes hippocampal cellular death and the consequent interruption of this inhibition, making the stress response more and more distinct, is a vicious cycle (Bears, Connors & Paradiso, 1999).

2.6.4.2 Mood disorders

When considering mood disorders, there are present the most profound variations in the ability to experience positive psychological states. The core feature appears to be a dysfunctional approach system. In the bipolar spectrum this feature is instead associated with increased appetitive activity and abnormal elevated mood (Clark , Watson, & Mineka, 1994). The subject affected by the mood disorder is unresponsive or overly sensitive to positive stimuli and rewarding experiences.

Depression is characterised by reduction in positive mood, and the loss of interest and pleasure in daily activities. Bipolar disorders are characterised by repeated maniacal and depressive episodes. Biological hypotheses state that this is due to a disorder in the production of monoamine, such as serotonin and noradrenaline in their neuromodulatory systems that involve the hippocampus, thalamus, hypothalamus and basal ganglia (Bear, Connors & Paradiso, 1999). Studies reported also show hypoactivity in the PFC, both in the dorsolateral and ventromedial divisions. These hypoactivations account for a lack of goal maintenance and sense-making. Reduction in the activity of the OFC accounts for a lack in reward and pleasure seeking, characterising one of the principal symptoms of depression: anhedonia (Ferssizidis, Kashdan, Marquart, & Steger, 2013). As we have seen in the previous section, when discussing pleasure reactions this symptom is also due to disruption in the reward system, especially at the level of basal ganglia. A decreased activation of ACC accounts for the effortful monitoring of experiences and outcomes of reward (Davidson, Pizzagalli, Nitschke, & Putnam, 2002).

CHAPTER 3: AUTOBIOGRAPHICAL MOOD INDUCTION PROCEDURE, A WAY TO ELICIT AND STUDY EMOTIONS: THEORETICAL FRAMEWORK, NEURAL BASIS, AND LIMITS OF THIS METHOD

3.1 Introduction

In this chapter we will summarise the principal procedures used to induce emotion, and specifically happiness, in laboratory research. We will focus on autobiographical recall, one of the most commonly used mood induction procedures (MIP), especially during experiments of neuroimaging.

We will then describe prior literature on the kinds of memory involved in this procedure and their neural correlates, focusing on memory for positive events.

3.2 Mood induction procedures

Many kinds of tasks and stimuli were designed and are still currently used to induce the mood or the emotion the researchers need to study during the experimental session. These tasks are normally called “mood induction procedures” (MIP).

In the study of emotions, many different MIPs have been developed (see Gerrards-Hesse, Spies, & Hesse, 1994; Westermann, Spies, Stahl, & Hesse, 1996 for reviews). Following work by Gerrards-Hesse et al (1994), they can be classified into 5 groups:

1) *MIPs based on free mental generation of emotional states.*

Stimuli are activated mentally by the participants themselves and they include:

- Hypnosis
- Imagination

2) *MIPs based on the guided mental generation of emotional states*.

The material used to induce emotion is presented to the subject with instructions to get into the target states, they include:

- Velten (self-referent statement describing self-evaluation and bodily sensations)
- Film/Story (including autobiographical recall)
- Music

3) *MIPs based on presentation of emotion-inducing material, without instructing the subject.*
   - Film/Story (including autobiographical recall)
   - Music
   - Gift (offer to the subject unexpected gift)
4) *MIPs based on the presentation of need-related emotional situations*. Presentation of situations that activate certain needs
   - Success/Failure (giving positive or negative feedback on the performance at a test)
   - Social interactions (exposing subject to interactions with confederates that are trained to behave in a manner typical of the target emotion. This method is based on the assumption that emotional state affects behaviour during social interactions)
5) *MIPs aimed at the generation of emotionally relevant physiological states*. based on the systematic variation of physiological states
   - Drugs
   - Facial expression (inviting subject to relax or contract specific muscles related to the expression of a prototypical emotion).

Experimenters often combine different type of MIPs to induce the target emotional state. The presented reviews discuss also the effectiveness of these MIPs, coming to the conclusion that Film/Story MIP and Gift MIP are the most effective in inducing elation and happiness. However, Imagination MIP and Velten MIP are the most effective in inducing depression. The same result is obtained using Film/Story MIP and Success/Failure MIP (Gerrards-Hesse et al. 1994). More specifically, the effectiveness of MIPs was greater in the induction of negative moods, but the presentation of films or stories accompanied with instructions to enter the specified state showed to be the most effective in inducing elation (Westermann et al., 1996).

More recently, Jallais and Gilet (2010) compared autobiographical MIP with music and guided imagery MIP. They confirmed a greater effectiveness of autobiographical recall in producing changes in arousal and valence.

Neuroimaging experimental designs need to involve the subject in some task that requires a particular ability or cognitive function in order to see which brain areas are activated when the brain uses that function. Experimental designs of this sort are usually constructed by contrasting a task able to elicit the studied function with a similar task that requires all similar abilities except the studied one (see chapter 1). Even when emotions are investigated, it is necessary for the required emotion to be felt or evoked by the subject during the scanning session. Yet, only some of the presented MIPs can be used during a neuroimaging session.

In the above cited review by Phan et al. (2002) the authors classified the reported PET or fMRI studies of emotion also on the basis of mood induction procedures, categorising 3 groups; visual MIP, auditory MIP and recall MIP. The presentation of visual stimuli is the most used induction method, followed by the recall of events methods.

In a currently unpublished review (Suardi, Sotgiu, Costa, Cauda & Rusconi, 2016) we sought neuroimaging studies on happiness, conducted with PET or fMRI techniques, using autobiographical recall methods, finding eight PET studies and seven fMRI studies (see Table 3.1 and Table 3.2). As claimed in that manuscript, a limit of these procedures is that every study uses the procedure of autobiographical recall implemented in a different way: within PET studies we found that five studies (Lane, Reiman, Axelrod, Yun, Holmes, & Schwartz, 1997; Lane et al., 1998, 2009; Marci, Glick, Loh, & Dougherty, 2007; Reiman, Lane, Ahern, & Schwartz, 1997) asked participants to listen to pre-recorded audio scripts of autobiographical emotional experiences. In the remaining three studies (Damasio et al., 2000; George et al., 1995; George, Ketter, Parekh, Herscovitch, & Post, 1996), subjects were cued to recall and relive personally-experienced emotional events selected during a pre-experimental session. As far as fMRI studies are concerned, in two of them (Cerqueira et al., 2008, 2010) pre-recorded auditory scripts of personal events were used to evoke happiness. Instead, in the remaining five studies (Markovitsch, Vandekerckhove, Lanfermann, & Russ, 2003; Pelletier et al., 2003; Sitaram et al., 2011; Zotev et al., 2011; Zotev, Phillips, Yuan, Misaki, & Bodurka, 2014) participants were instructed to imagine and relive autobiographical emotional events with different types of cues. It is furthermore necessary to highlight that every participant has their own concept of what happiness is, and this can activate different brain regions. Finally, recalled events are not easy to compare in terms of vividness, richness of sensory and physiological details and motor actions made in the recalled event and, thus, in terms of correlated brain activations. All these differences make activations correlated to recalled events not easily comparable.

In a prior study (Sotgiu, Viganò, & Suardi, 2014) was also found that participants were able to recall a minimal number of relevant happy events in their life. Considering the amount of registration needed for contrasts in fMRI studies, we raised doubts about the pertinence of autobiographical recall as the best MIP for these types of study.

3.3 Event memory and autobiographical memory

We held that autobiographical recall is one of the most-used and most effective MIPs to use during neuroimaging experiments. We now give consideration to the different kinds of memory, abilities required and the network involved during the recall of events.

Event memory requires the construction of a scene from the past or future, either real or imagined (Rubin & Umanath, 2015). Event memory is part of explicit memory. To construct an event, memory is necessary to place oneself in a space and time, allowing a sense of relief in an egocentric perspective (first person or third person). This sense of reliving, often called “*autonoetic consciousness*”, is what makes event memory different from semantic memory and knowledge in general, (Szpunar & McDermott, 2007, 2009) including any memories recollected in a conscious way (Graf & Schacter, 1985).

Considering everyday experiences, event memory is the ability used to think of prototypical events like a meal with family. It is possible to imagine the scenario, which family members are present at the meal, where they are sat and the things which are done together, irrespective of whether or not that specific meal ever happened, or if it happened many times in your life. Knowledge in terms of remembering the past and constructive processes are necessary to construct it.

Rubin and Umanath (2015) in their cited review confront the problem of a lack of clear definition between autobiographical memory, event memory, episodic memory and semantic memory. They claim that *semantic memory* is the general conscious memory, "*episodic memory* is a type of *event memory* with a sense of reliving, about the self (unique and voluntarily recalled), while *autobiographical memory* is a general term for memories related to the self" (p. 16, Rubin & Umannath, 2015). Hence, the distinction is subtle but to summarise event memory is more general and related to prototypical events that could normally happen more often and about which the event can modeled with defined features. Episodic memory instead is involved in reliving a specific event, not necessarily related to the self and which has not necessarily yet happened. Finally, autobiographical memory is the memory of events in which the subject is the protagonist. For other researchers, autobiographical memory is a wider concept that includes both episodic and semantic memory (Baddeley, 2012; Butters & Cermak, 1986; Kopelman, Wilson, & Baddeley, 1989). It is notable that different researchers use the term in different ways. In the theory of Rubin and Umannath (2015), event memories are constructed when they are recalled.

3.4 Neural basis of memories required to draw a personal history

Reviewing the literature, academics state that the hippocampus and related structures in the medial temporal lobe are crucial brain regions for event memories, and about their function scholars claim:

> The hippocampus and surrounding areas contribute to binding at encoding and to the construction of detailed visual images at recall; consequently, hippocampal damage results in a lack of event memories. The hippocampus, however, is not needed for memories that are linguistic descriptions of past events, navigation, and other tasks that do not require detailed images. The roles of the hippocampus in spatial cognition and in memory for events are typically discussed separately, but they integrate naturally in event memory. (p. 8, Rubin & Umanath, 2015)

Other key regions for event memory are the visual cortex and scene-related areas in the ventral stream, like the parahippocampal place area, retrosplenial cortex (Rsp) and the occipital place area.

Episodic memories are event memories for unique experiences both in the past and in the future. Tulving (1972) defines episodic memory as a memory system coding for information about facts of the sort “I did such and such, in such and such a place at such and such a time”. Tulving’s definition was refined, adding the concept of autonoetic consciousness. Furthermore, he added the concept of a similarity between memories and imagined future events (that we will better describe in next chapter) with the distinction between remembering and knowing (Tulving, 1985, 2002).

In the real world, the distinction between episodic memory and semantic memory (knowledge) is of course hard to apply and recognise. Although true that they interact and overlap in many ways (e.g. we can use episodic memory to remember an event in which we learned something that is now part of our semantic memory),it is reasonable that they are constructed from the same stored information. For most theories, narrative is a key feature of episodic and autobiographical memory (Rubin & Umanath, 2015). Cabeza and St Jacques (2007), in their review define episodic memory as “the ability to remember past events from one’s own life”. The authors stated that there are three processes that can be studied researching autobiographical memory and they are i) constructive processes, involving searching, monitoring and self-referring, mediated by activity in prefrontal regions, ii) recollective qualities of emotion and vividness, mediated by the amygdala, hippocampus, Rsp and visual cortex (occipital, cuneus and precuneus), and iii) remote memory retrieval mediated by the hippocampus. In particular, constructive processes are linked to activity in different prefrontal regions; the left lateral PFC is involved in memory searching and retrieval processes while the vmPFC is involved in monitoring and the mPFC is involved in self-referential processes.

As we can see, it is hard to find in relevant publications a clear cognitive distinction between different kinds of memory involved in the recall of past personal events, so we will nominate autobiographical memory the ability needed for these kinds of tasks.

3.5 Neural basis of autobiographical memory for positive emotion

In attaining the goals of this dissertation, it could be also useful take a look at processes and neural areas involved in autobiographical memory for emotion, especially for positive ones. Traditionally, studies in this field aim their focus towards the above-described *reward processing*. Within the *dopaminergic system*, neural bases of reward individuation, anticipatory process, and foresight of future rewards were identified. Key regions were found in the VS, dorsal striatum (caudate nucleus), OFC and amygdala.

Other theories suggest two distinct neural systems for the elaboration of autobiographical positive memories. One is linked to the elaboration of arousal components and involves the amygdala and hippocampus, while the other is linked to the elaboration of valence components and involves the PFC and hippocampus (Kensinger & Corkin, 2004).

Emotional memories are memories of episodic events that elicited emotional reaction. Research demonstrates that emotion can influence memory in many ways. The influence of emotion operates at different stages in memory, including encoding and consolidation, as well as the retrieval process. Encoding refers to the process of memory formation. This process is modulated by automatic influence that acts when attention is captured by some stimuli within the "whole" perceived that are processed in a systematic way. Also, more-controlled processes can influence encoding; for example rehearsal and voluntarily-focused attention given to the emotional event. High-arousal emotional stimuli are more easily encoded. It seems that the amygdala is the principle agent responsible for this influence, but it is not alone. It requires the participation of other structures and areas. First is the hippocampus, but there are also sub-regions of the OFC, ACC and caudate nucleus that help to focus attention. Encoding lower arousal events seems to engage more controlled processes. The role of these processes is to link acquired information to stored semantic knowledge or different episodic experiences into a personal self-view (See Fig. 3.1) (Holland & Kensinger, 2013).

Fig. 3.1 Different stages of autobiographical memory

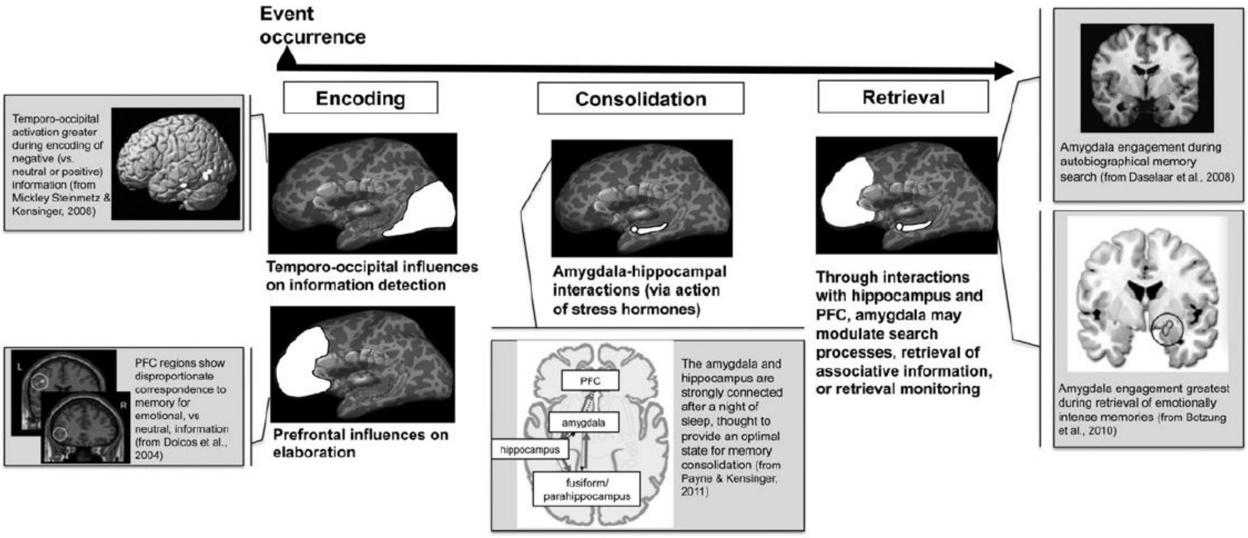


Image by (Holland & Kensinger, 2013)

Furthermore, emotional valence is reported to be able to influence memory at the stage of encoding. Recent studies suggested a greater involvement of the link between the amygdala and hippocampus for negative memories, while in positive memory the links between the hippocampus and PFC are stronger (Ritchey, LaBar, & Cabeza, 2010). Finally, emotional states and emotional goals can also influence the stage of encoding a memory. For these reasons, memory can be considered a constructive process.

Emotion could also affect the consolidation phases. While during encoding, emotion seems to reinforce memory, during consolidation emotion may influence the memory for all aspects of the event. It may make some of the details available and make some others unavailable for later retrieval.

Autobiographical retrieval is a process that involves many neural areas that overlap other areas related to the encoding process, including the medial temporal lobe, medial and lateral prefrontal lobe, medial and lateral parietal lobe. The hippocampus has a crucial role in the reconstruction of a memory. What is more, retrieval can be modulated by emotional activation through the influence exerted by the amygdala to the hippocampus.

Retrieving a memory activates many emotional details of the emotion perceived during the encoding phase. This process seems to be orchestrated by the PFC (Holland & Kensinger, 2013).

In the review of Phan et al. (2002) neural correlates of autobiographical recall when used as induction mood procedure are given. They are the insula, together with the ACC. Activation of these two sites correlates with cognitive demand. Across the reported studies and in that review it was not possible to find a single region associated to emotion in general. Only mPFC was a common activation, not specific to any emotion. Conversely a clear involvement of basal ganglia was reported during happiness, especially the VS for reward motivation and pre-goal attainment.

In the above cited work (Suardi et al., 2016) regarding neuroimaging studies using autobiographical recall methods to stimulate activations of happiness, we demonstrated the involvement of many different areas and distinctive patterns, such as parietal cortices and sensorial regions, the thalamus and hypothalamus, temporal regions like the amygdala and hippocampus and subcortical structures such as the basal ganglia (especially VS and caudate). They can all be found in neural models of emotion (see chapter 1). Actually, a clear common agreement across studies was found in relation to the ACC, PFC and insula. Most of the 16 reported studies found increases of activations in these areas. In this discussion, we highlight how these areas proved crucial also for other recalled emotions (Murphy, Nimmo-Smith, & Lawrence, 2003), and are not specific for happiness. We hypothesise their involvement in both positive and negative emotive autobiographical recall, with the role of placing self in memory and in general self relevant mental activity for PFC (D'Argembeau et al., 2007; Johnson et al., 2006; Kelley et al., 2002; Macrae, Moran, Heatherton, Banfield, & Kelley, 2004; Ochsner et al., 2005; Philippi, Duff, Denburg, Tranel, & Rudrauf, 2012; Zhu, Zhang, Fan, & Han, 2007). PFC is crucial also for representation of decision values (Chib, Rangel, Shimojo, & Doherty, 2009), and behavior related to reward (Kringelbach, 2005; Öngür & Price, 2000). ACC is especially involved in cognitive demanding task to induce emotion and in social emotion (Phan et al., 2002) as in self relevant processing (D'Argembeau et al., 2007; Han et al., 2010; Johnson et al. 2006; Zhu et al., 2007). Insula is involved in the processing of interoceptive memories (Cauda et al., 2012; Gasquoine, 2014; Phan et al., 2002). These regions resulted crucial also for mechanisms of mood disorders (e.g., Davey, Harrison, Yücel, & Allen, 2012; Philippi, Motzkin, Pujara, & Koenigs, 2015; Sperduti et al., 2013; Takahashi et al., 2010; Yoshimura et al., 2014; for a review, see Nejad, Fossati, & Lemogne, 2013). Future researches are necessary to clarify the dynamics and the pattern of activations of more specific regions within these areas during happiness. In table 3.1 and table 3.2 are reported PET and fMRI studies using autobiographical recall like MIP for eliciting happiness, contrasted conditions, technique of recall induction, the sample's characteristics and activations found in each study.

Table 3.1 *PET studies (in chronological order by publication date)*

Study	Contrasted Conditions	Tecnique of Recall Induction	Participants' Characteristics	Neural Correlates of Recalled Happiness	
George et al. (1995)	Happiness, Sadness, Neutral	REC/REL Two experiences for condition cued with pictures of human emotional faces	11 females, AGE: 33.3, SD: 12.3	+ ACC - R PFC - TPC	
				Men	Women
George et al. (1996)	Happiness, Sadness, Neutral	REC/REL two experiences for condition cued with pictures of human emotional faces	10 females, AGE: 34.5, SD: 12.1 10 males, AGE: 35, SD:8.8	+ R caudate + L putamen + L superior FG	+ L ACC + R caudate + L inferior FG + precentral gyrus +cerebellum
(1) Lane et al. (1997); (2) Reiman et al. (1997) (3) Lane et al. (1998) (4) Lane et al. (2009)	Happiness, Sadness, Disgust, Neutral	LIS.SCRIPTS Three experiences for condition and film clips	12 females, AGE: 23.3, SD:3.2	+ ventral mesial FC + ventral striatum + caudate + medial PFC + midbrain + L mid insula	
Damasio et al. (2000)	Happiness, Sadness, Fear, Anger, Neutral	REC/REL One experience for condition	21 females, 20 males divided into four cohorts, AGE: from 24 to 42	+R INS +R somatosensory cortices +R PCC +R e L posterior cingulate +L ACC -/+ R ACC + R OFC + L basal forebrain + R hypothalamus + L midbrain.	
Marci et al. (2007)	Happiness, Anger, Sadness, Neutral	LIS.SCRIPTS Two experiences for emotion	5 females, 5 males, AGE: 33.9, SD: 11.9	+ L ventral striatum + L anterior/ R superior/L middle TG	

Note. REC/REL = recalling and relieving past emotional experiences; LIS.SCRIPTS = listening autobiographical scripts; + = activation; - = deactivation; R = right; L = Left; ACC = anterior cingulate cortex; FG = frontal gyrus; OFC = orbito frontal cortex; PFC = prefrontal cortex; FC = frontal cortex; INS = insula; TG = temporal gyrus; TPC = temporo parietal cortex; PC = parietal cortex.

Table 3.2 *fMRI studies (in chronological order by publication date)*

Study	Contrasted Conditions	Tecnique of Recall Induction	Participants' Characteristics	Neural Correlates of Recalled Happiness
Markowitsch et al. (2003)	Happiness, Sadness, Rest	REC/REL 18 experiences for condition with key words as reminder	7 females, 6 males, AGE: 30 (range: 19-43)	+R posterior TG + R ACC + L medial/superior FG + L precuneus + L VP + L amygdala
Pelletier et al. (2003)	Happiness, Sadness, Neutral	REC/REL One experience for condition	4 females,5 males professional actors, AGE: 33 (range: 25-41)	+ OFC + medial PFC + Lventrolateral PFC + L anterior temporal pole + R pons
(1) Cerqueira, et al. (2008) (2) Cerqueira et al. (2010)	Happiness, Irritability, Neutral	LIS.SCRIPTS Three experiences for condition	5 females, 6 males, AGE: 32.4 ± 7.2	+ L PFC + L anterior/ R posterior INS + L ACC + L hypothalamus/ thalamus + L/R middle TG + R TC
Sitaram et al. (2011)	Happiness, Disgust, Sadness	REC/REL One experience or more for condition with pictures (International Affective Picture System) as reminder	12 volunteers, AGE: N/A	+ medial OFC /antero-rostral FC + ACC + INS
Zotev et al. (2011)	Happiness, Count, Rest	REC/REL 3 experiences for condition with the word "happy" as cue	28 males, AGE: 28 ± 9	+ R PFC + L superior FG + L/R TG + L amygdala + L hippocampal regions + L/R hippocampus + ACC + PCC
Zotev et al. (2014)	Happiness, Count, Rest	REC/REL Three experiences for condition with the word "happy" as cue	4 females, 2 males, AGE: 24 ± 9	+ L/R INS + R OFC + R PFC + ACC + R superior TG + lingual gyrus

Note. N/A = not available; REC/REL = recalling and relieving past emotional experiences; LIS.SCRIPTS = listening autobiographical scripts; + = activation; - = deactivation; R = right; L = Left; ACC = anterior cingulate cortex; PCC = posterior cingulate cortex; FG = frontal gyrus; OFC = orbito frontal cortex; PFC = prefrontal cortex; FC = frontal cortex; INS. = insula; TC = temporal cortex; TG = temporal gyrus.

3.6 Limitation of autobiographical mood induction procedures

Autobiographical recall is a greatly effective and widely used mood induction procedure. As claimed before, few study compared its effectiveness to other methods' effectiveness (Gerrards-Hesse et al., 1994; Jallais & Gilet, 2010; Westermann et al., 1996). Nevertheless, it is evident how literature lacks a deep reflection on it and a clear operationalisation of this method. The cited unpublished review (Suardi et al., 2016) focus its attention on the use of this method to elicit happiness and it ascertains that autobiographical recall presents some methodological limits that could increase difficulty in the interpretation of results across different studies.

First, the lack of a operationalisation lead researcher to the implementation of this methods in different ways, using many different cues (written instructions, pictures, emotion-related words, human faces expressing emotion, or film clips or auditory scripts) to guide subject during recall and building different experimental procedures. These differences make comparisions across studies a difficult task.

Second, none of the reviewed studies asked participants about the features of the recollected memories: sensory details, physiological reactions, amount of movement made during the recollected event and subjective feelings could vary significantly across different memories, even within the same subject. This may increase intra-variability when comparing different memories recollected by the same subject and inter-variability when comparing memories recollected by different subjects.

Finally, considering research about happiness, none of the reviewed studies defined a distinction between hedonic and eudaimonic happy memories: in light of the literature presented in the second chapter, activations related to these two kinds of happiness may be different, and that could increase at the same time both intra- and inter- variability.

Considering these limits, the implementation of a new method, able to control more confounding variables respect to autobiographical recall MIP, was deemed to be necessary for the present study, in order to overcome the depicted limitations. The next chapter provides to describe this new method and its neural basis.

CHAPTER 4: TOWARDS A NOVEL MOOD INDUCTION PROCEDURE TO STUDY EMOTION

4.1 Introduction

The method proposed for this study is an original mood induction procedure consisting of the imagination of events chosen by participants as truly happy if they occurred in the moment the research took place.

Similar procedures in relevant literature on the topic of emotion induction were not found. Therefore, in this chapter the cognitive abilities considered to be involved in the procedure used in the present study are described.

First is *mental time travel* ability. This cognitive ability is considered archetypal of human beings and it is necessary both to recall past events and to imagine future events. We will then consider other abilities such as *episodic future thinking, daydreaming* and *transportation into narratives*. Shared features between these constructs and the recent defined *Brain's Default Network* (BDN) are, then, highlighted. BDN is a resting state network recently described by literature. Studies about BDN are growing in the last decades and the involvement of this system in many different cognitive abilities is demonstrated over and over again by researchers. BDN is a system that showed to be perturbated by tasks with cognitive demand; it is hypothesised to be a network in which self-awareness and consciousness are located.

Finally, similarities and differences between all these mental processes and the abilities required during the procedure used in the study described in this dissertation are provided in a separate section (4.7).

4.2 Mental time travel

In recent years, much attention has been given in the scientific research to an ability called "mental time travelling" (Tulving, 1985). This ability allows one to remember past events and imagine future events. Episodic (or autobiographical) memory is only a part of this system able to provide the basis for travel into both the past and the future. We continuously travel into the future. Every day we plan the day or week ahead, our goals and our dreams and we become engaged in imagining how the future could be in order to face it, to enjoy it and to change our plans in accordance with what really happens over the course of time.

Some of areas of the brain considered to be the basis of mental time travel overlap with certain areas thought to be regions of BDN, and mental time travel is definitely one of the activities in which the BDN is engaged.

"Autonoetic consciousness" is considered to be one of the characteristics of BDN. It is also the ability required to undergo mental time travel. "We can vividly recollect our personal past and, we can also, with a seemingly equal level of vividness and efficacy, travel forward in time to preexperience our personal future" (p. 120, Szpunar & McDermott, 2007; 2009). BDN is described in more detail in paragraph 4.6.

In recent studies, much evidence supports the idea that travel into one's personal past and personal future shares psychological and neural processes. Tulving (1985) first suggested this overlap, describing a case of an amnesic patient (K.C.) unable to perform both tasks after a trauma to frontal and medial temporal lobe. Other patients with similar lesions and similar difficulties were then reported by other studies (e.g. Klein, Loftus & Kihilstrom, 2002; Hassabis, Kumaran, Vann, & Maguire, 2007) adding to the notion that the ability to travel into the subjects' impersonal past or future was affected. The study of Hassabis et al. (2007) demonstrated that in a sample of 10 patients with brain damage to the hippocampus, the ability to imagine the future was compromised, especially in terms of spatial coherence; while imagining a beach, patients were only able to describe vague features like a blue sky, as opposed to more detailed descriptions of controls. This study highlighted the importance of the medial temporal lobes for the ability to bind together basic elements from memory in order to create coherent images. Further evidence came from the study of onthogenetic development: both abilities emerge together at the same developmental stage. At the age of approximately 4, children are able to recollect personal events and to imagine future events, as they become able to plan future actions. In general, children before the age of 4-5 do not seem to be able to mentally consider a state that they are not experiencing in that moment. Both abilities decline almost simultaneously during the aging process, especially in terms of the lack of details pertaining to retrieved events much as with future scenarios (Szpunar & Mc Dermott, 2007; 2009). A set of evidence also emerges from studies on clinical populations like the majorly depressed (Evans, Williams, O'Loughlin, & Howells, 1992; Williams, 1996; Williams & Broadbent, 1986; Williams & Dritschel, 1988) or schizophrenics (Danion et al., 2005; Feinstein, Goldberg, Nowlin, & Weinberger, 1998; Riutort, Cuervo, Danion, Peretti, & Salame, 2003; Wood, Brewin, & McLeod, 2006). These patients have been shown to be less capable of vividly recollecting personal events from the past and imagining future events, in respect to control participants.

This evidence was corroborated by functional brain imaging studies using PET or fMRI. Similar areas, involving the occipital cortex, the PCC and medial temporal lobes were engaged during both types of mental time travel (Addis, Wong & Schacter, 2007; Okuda et al., 2003; Szpunar et al., 2007; 2009) (See Fig 4.1). Addis and Schacter (2008) suggest a distinction, indicating two neural subsystem of the core network involved in mental time travel. Following this hypothesis, a system is formed by the anterior hippocampus, mPFC and IFG and is more active during the general imagination of events (both in the past and in the future), while another system formed by the hippocampus, parahyppocampal gyrus and posterior visual cortex is more active during the retrieval of past events rich in contextual and visuospatial details.

Considering that imagining the future requires a continuous reconstruction of new scenarios and a recombination of stored actions, other studies reported that during imagination there is greater activity in the hippocampus, lateral premotor cortex, medial posterior parietal cortex and posterior cerebellum (Szpunar et al., 2007; 2009).

Bearing in mind all these considerations, we can conclude that processes and brain networks activated by remembering the past and imagining the future are closely linked. We can thus suppose that imagining the future has a similar effect to remembering the past in inducing specific emotions.

Fig 4.1 Similarities (A-C, superior occipital cortex, posterior cingulate, medial temporal lobes) and differences (D-F, lateral premotor cortex, posterior medial cortex, right posterior cerebellum) between imagining the future and remembering the past

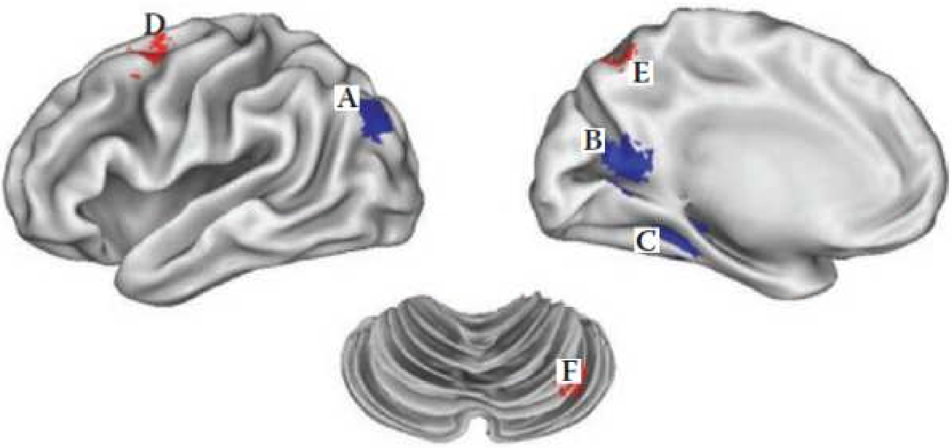


Image by (Szpunar & Mc.Dermott, 2009, p.124)

4.3 Episodic future thinking

The specific ability of envisioning possible future scenarios and mapping multiple versions of the future has been called "episodic future thinking" (Atance & O'Neill, 2001). This ability allows the consideration of possible outcomes of personal action and long-term reasoning about future goals, through the inhibition of immediate impulses. In this way it has an adaptive value. The process of future envisioning involves multiple components. First, it requires the retrieval and integration of stored information from memory. Next, it requires processing subjective time. Finally, it also requires self-relevant processing. Indeed, envisioning the future is not only the retrieval and recombination of past details, but it deals with personal goals. Neuroscientific research has revealed neural correlates of this process within a specific set of regions that includes the mPFC, medial and lateral temporal regions, PCC/Rsp and inferior parietal lobule (IPL) (Szpunar & McDermott, 2007; 2009). As already stated, these regions are included in BDN and are associated with other functions such as autobiographical memory, the theory of mind and navigation.

D'Argembeau et al. (2010) investigated a neural basis of self-referential thinking in personal-goal-processing. They asked participants in prescan interviews about personal goals. During fMRI, scan participants were required to think about future events involving personal goals; plausible future events unrelated to personal goals and routine activities as a control task requiring the mental construction of plausible events without positioning themselves in subjective time. The comparison between personal and non-personal future events revealed activation in the ventral mPFC and PCC while participants thought about future events related to personal goals. Scholars discuss this in their study regarding the role of these areas in goal processing, suggesting a specific role for mPFC in coding the relevance of the imagined event to the self. PCC proved to be very active during the generation of contextual association. Some evidence showed its role in relation to familiar context with respect to unfamiliar ones. Less activation during the imagination of routine activities (that usually take place in more familiar context) give proof against this interpretation. D'Argembeau et al. (2010) then claims that it is responsible for putting self-relevant information in context and for integrating this information with other self-relevant knowledge. The role of these regions in episodic future thinking is still debated and requires further investigation.

4.4 Daydreaming

As the word indicates, *daydream* is an experience by which we are engaged every day. It appears to be a fundamental component of subjects' functioning, and it is a mental activity that involves a number of processes. First, Freud (1953) defined it as a mental activity that departs from reality, including thinking about the self or others acting both in realistic and unrealistic ways. Another definition of daydreaming comes from Singer (1966), who described it as thought unrelated to ongoing activity. Klinger (1971) defined daydreaming as unintended mental content that comes to mind spontaneously. Klinger (2009) provides another definition, stating that daydreaming is a "nonworking thought: it includes mindwandering and instances when people decide to daydream about something, and let their minds run."(p. 226).

Daydreams prove to be an integral part of each individual; they are affectively toned and linked to preceding cues and tend to drift and reflect a person's personal traits.

Research about daydreams suggests that they have a median duration of 5 seconds and a mean duration of 14 seconds (Klinger, 1978). During daydreaming thoughts appear to be predominantly undirected and fanciful; they are related to the external world and are mostly directed and controllable. They are generally characterised by some kind of sensory experience in terms of vividness, sound or internal speech. Cues able to determine the direction of daydream are often personal goals and personal current concerns. This appears to be especially true when actions related to goal pursuit are blocked by the context or are inappropriate to the moment they arise to mind; daydreaming is the result of these blocked actions that try to continue in the form of mental images and thoughts (Klinger, 2009). Evidence describes as mind wandering entails activity in the BDN (Mason et al., 2007); when the mind is at "rest" the person processes their more pressing goals. This activity continues during sleep. Studies show that goal-related dreams are more common during periods of personal goal attainment. Their function could be to plan goal attainment, as is demonstrated by the correlation between the number of daydreams and relative percentage of goal attainment (Klinger, 2009)

4.5 Transportation into narratives

"Telling stories is a universal human activity" (p. 241, Green & Donahue, 2009). Hearing or reading stories is an activity in which we are engaged from infancy. It is a kind of guided mental simulation. Psychological study demonstrates that transportation into narratives has powerful effects on emotion and persuasive consequences (Green & Brock, 2000). Narratives are sequences of inter-connected events and characters. These events can be fiction or factual. When there is transportation into narratives, the individual can react as if he were part of the story. Transportation is a pleasant state, and this is often true even when events are negative or dramatic, as is the case with thriller or horror stories. One reason for this can be found in the process of "leaving-reality", that allows distance from self criticism.

It likely relies on processes similar to those implied by other mental simulations, but has peculiar characteristics. It is somewhat correlated with empathy, contributing to the general tendency to be absorbed in experiences. It could be defined as a kind of reflective thinking, in which a subject simulates other worlds; comparing themselves to another standard. This activity seems to be preconscious and in a certain sense automatic (Green & Donahue, 2009).

Noteworthy is that when a first-perspective-view is used, increases in psychological closeness to characters and self-involvement in emotional states were demonstrated (Holmes, Coughtery, & Connor, 2008). Furthermore, the emotional state, when is imagined respect to when is really felt, tends to be overestimated. This was found to be true even when people were invited to think to the future. People tended to underestimate that other events might affect the emotion experienced in a particular moment, imagining greater intensity and duration of future emotions. Actually, when an emotion is really felt, it rarely is a pure emotion, but it often is contaminated by other events, other emotions or other cognitive evaluations (Wilson & Gilbert, 2005).

Some factors increase transportation, such as the individual's ability to imagine, story-telling and writing ability, general transportation tendencies and familiarity with the aspects of the narratives.

Studies on the neural basis of transportation have not yet diffused. Little data is present in literature on the topic (Mar, 2004) and they suggest the involvement of the frontal, temporal and cingulate cortexes, especially regarding the involvement of working memory, the theory of mind and BDN. Yet, this remains an unfulfilled avenue of research (Green & Donahue, 2009).

4.6 Brain's Default Network

Giving consideration to the copious references made thusfar to BDN in this dissertation, a wider description and explanation of its anatomy, its function and its relevance is necessary.

Brain's Default Network is considered the neural correlate of the stream of consciousness, fantasy, imagination, daydreams and thought. The BDN consists of a set of distinct, anatomically-connected brain areas or systems which interact with one another. They result in engagements when the subject is not involved in any cognitive tasks and is left to think to themselves. Most likely is that its first function is to evaluate and anticipate personal events before they happen, in order to prepare the subject for them. BDN thus facilitates self-relevant mental flexibility.

The network was discovered accidentally, when researchers using neuroimaging (beginning with the Swedish brain physiologist David Ingvar) noticed that during resting state scanning, the same common set of regions became very active.

BDN includes association cortex and spare motor and sensory cortices. The components include "In particular mPFC, PCC/Rsp and IPL, together with the hippocampus and areas in the medial temporal lobe considered loci of episodic memory". (Buckner, Andrews-Hanna, & Schacter, 2008). There is evidence indicating that these areas contribute to different functions within BDN. As Fig. 4.2 and Fig 4.3 describe, the interconnected subsystems in which BDN is organised converge on key hubs, amongst these the PCC/Rsp, vmPFC and IPL. dmPFC and hippocampal formation (HF) are strongly linked to the core hubs of BDN (mPFC and PCC) but not to one another (Buckner et al., 2008).

Fig 4.2 Hubs and subsystem identified in the Brain's Default Network

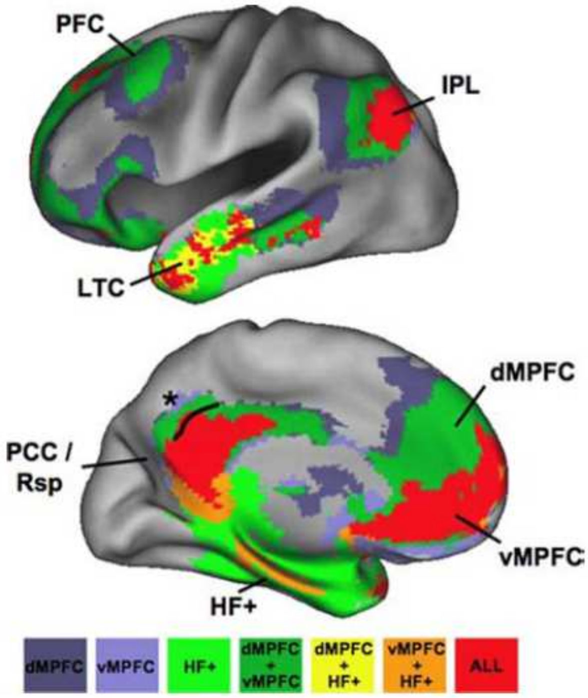


Image by (Buckner et al., 2008, p. 12)

Fig 4.3 Main region and connections within BDN

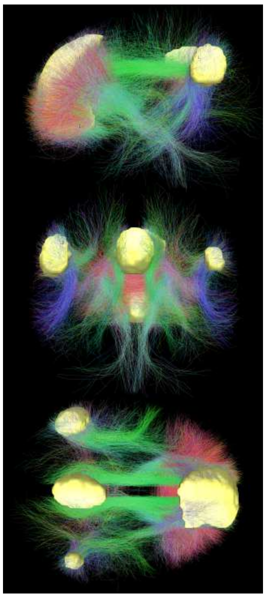


Image by (Horn, Ostwald, Reisert, Blankenburg, 2013)

The observation that BDN was most active during passive tasks pushed researchers to think of it as responsible for spontaneous cognition, mind wandering, fantasy, imagination and daydreaming as the major activities of a mind which is not involved in a cognitive task. Even during cognitive tasks, increased activity in some regions of the BDN (PCC/Rsp and region near IPL) seems to predict lapses in attention, as the subject falls into a more private channel of thoughts.

Even if the BDN seems most active when attention is given away from external stimuli, there are a number of tasks that directly activate the BDN and can help to better understand its functions. One hypothesis allocates the BDN the role of “sentinel”, with a low level of awareness of the environment without active exploration in order to be ready to give more attention to an unexpected stimulus. Other evidence supports the idea that BDN activation accounts for the construction of mental simulations based on past experiences, as happens during remembering, yet also during future thinking and imagining alternative perspectives. This includes when those perspectives belong to another person. The BDN has been thought as playing a role in the formation of the theory of mind and in moral decision making. Investigation of all these functions showed strong overlap with regions of the BDN. In all presented hypotheses’, the BDN seems important in the anticipation of what is to happen.

The two subsystems considered, the medial temporal lobe subsystem seems to be more active in processes requiring the retrieval of information from stored memories, while the mPFC subsystem seems to be more involved in processes which refer to the self, to its relation with others and to self-relevant simulation. The PCC may serve for interaction between these two subsystems.

Intriguing hypotheses have been proposed indicating the disruption of BDN as the cause of brain disorder like Autistic Spectrum Disorders, citing a reduced ability in the formation of the theory of mind. Other diseases linked to BDN’s disruption could include Schizophrenia, reflecting the over-activation of mental simulation. An involvement of BDN was also proposed in Alzheimer’s Disease (AD). Regions composing the BDN are the first which show atrophy during an onset of AD. The proposed hypothesis states that an over-activation of BDN throughout an individual’s life (due to a genetic disposition) could contribute to an accumulation of beta-amiloyd plaque that causes pathological consequences in the regions composing this system (Buckner et al., 2008).

4.7 A novel way to study emotion

Considered together, the mentioned literature helped us to define the task we used to induce emotion and allows us to claim that the task we used shares some features with all other constructs presented in this chapter. We asked participants to choose events that they consider happy from a list, and then presented a script describing sensations, emotions, actions and interoceptive feelings of each event, asking them to empathise with the told story. During the fMRI session, we presented selected events using sentences extracted from the script. This task is clearly a type of episodic future thinking exercise made possible by the mental time travel ability. In some ways it is also a kind of daydream scenario. However, we cannot consider it to be purely a task of future thinking, because in some way we are forcing people to think about a possible future, but also not a pure daydream, because the imagined event did not arise freely in the participants mind. In addition, as we will describe in more detail in next chapter, some of the chosen events could have already happened to the subject, possibly in a similar but slightly different way. We can however say that we immersed them in a narrative experience matched with personal goals, value and desires, in line with the choice within the list made by participants.

We consider this procedure to be suitable to study emotion considering that imagined emotion tends to be overestimated by people and also considering that participants can be guided in feeling emotion through narratives that allow thinking about not real events as it happens during mental time travel or daydreaming. All of this while controlling confounding variables.

CHAPTER 5: A STUDY OF THE NEURAL CORRELATES OF HEDONIC AND EUDAIMONIC HAPPINESS

5.1 Introduction

The presented overview of extant literature shows a growing interest of neuroscience in detecting neural correlates of emotions and in better understanding the processes that underly the emotional brain. As we previously claimed, an emotion is a phenomenon composed by multiple processes, that involves both mechanisms able to elicit emotion and emotional response, focused on relevant objects, and characterised by brief duration. We can argue that happiness shows all these features and, in fact, it is definetly considered and studied as an emotion by affective neuroscience.

From the beginning of the new century, Positive Psychology pointed the focus of its studies on positive emotions instead to increase knoweledge of corrupted brain mechanisms and illnes as traditional psychology did. In this field, psychological literature and scientific reflection about happiness growth, leaving the boundaries of philosophy. Accepting previos philosophical definitions, psychologists deepened the study of happiness, drawing basically the existence of two kinds of happiness: hedonic and eudaimonic.

Hedonic happiness is what we feel during experiences of deep psychological or physical pleasur while eudaimonic happiness is more linked to self-realisation, sense making and goal striving. Noteworty is that psychology accepted this distinction while the same distinction is not still adopted by studies in the field of affective neuroscience: none study was found investigating these two kinds of happiness. Only some hypothesis were proposed.

Considered that, usually, personal events make the subject involved in one of the two different kinds of happiness, we originally elected autobiographical recall as the best way to investigate neural correlates of hedonic and eudaimonic happiness. Nevertheless, exploring literature, doubts about this methods arose: autobiographical memories are very different between each other even within the same subject in terms of contents and, thus, in terms of neural correlates. This make difficult a comparision between different memories: as the literature showed, reviewing previosu studies, this procedure was implemented in many different ways and distinctive neural patterns were identified by each different study. Furthermore, relevant happy events could be few in a lifetime and the number a subject is able to recall could not be enough, considered the amount needed for fMRI registration.

To overcome these limitation, we proposed for this study, the use of a new method. As a mood induction procedure we used a MIP based on the guided mental generation of emotional states, a variation of autobiographical recall. This method brings with it some advantages for use with the fMRI technique. First, guiding the subject to imagine emotional events, researchers can increase the number of used stimuli: the subjects are not required to imagine only really occurred relevant events, but they must choose a defined number of events within a given set of plausible events. The chosen events are the ones considered relevant by each subject. The felt emotion is not corrupted by concurrent negative memories but it tends to be pure.

Furthermore, guiding the subject in imaging events allows a standardisation of the stimuli, making them comparable between each other. In detail, we guided each subject to imagine different features of the chosen events: all presented events were structured to describe the same features (sensorial details, emotional feelings, interoceptive activations, movements made during the event) that were selected reviewing literature about mental time travel (D'Argembeau, & Van Der Linden, 2004; Rubin, & Umanath, 2015; Szpunar, & Mcdermott, 2007; 2009). The behavioural domains categorised by Human Brain Mapping research (Lancaster et al., 2012) were also considered. Furthermore, to make the events comparable in terms of motor activations, we proposed two different sets of events: one characterized by high amount of movements made by the subject and another one characterized by low amount of movements made by the subject. These original methodological precautions, together with theoretical considerations presented in the previous chapter, allow us to consider this procedure appropriate for the study of emotion.

5.2 Aims

The study at hand attempts to increase knowledge about neural correlates of happiness. More in depth it was designed to investigate, in a sample of healthy participants, whether or not it is possible to find a distinction in neural activity related to the two psychological states of hedonic and eudaimonic happiness. The investigation of the differences between hedonic and eudaimonic happiness was done by asking people to imagine and empathise with events which have not necessarily occurred in their life as though they were happening in that moment.

First, considering that the procedure used shares features with many cognitive abilities whose neural correlates overlap with the Brain's Default Network, we expect great involvement of this network or at least of some of its components during the guided imagination. We hypothesise, then, that both hedonic and eudaimonic happiness involve cortical and subcortical structure considered part of the emotional brain, especially regard to those areas related to self-referential processes and pleasure coding. We, finally expect a greater involvement of hedonic circuitries during the hedonic condition while we expect a greater involvement of neural areas related to self-referential processes and sense-making during eudaimonic happiness.

5.3 Method

5.3.1 Participants

Seventeen subjects (7 males, 10 females) aged between 20 and 40 years old (mean age: 25,06, SD =5,05) took part in the study. The mean ages of male and females were uniform. 14 participants out of 17 were unmarried and 13 participants were ungraduated students, only 4 participants had a job but from less than 5 years. Web advertisements that asked people to participate in research about neural correlates of happiness were used to recruit participants. Subjects were screened for fMRI compatibility. All of the participants gave their informed written consent in line with the Declaration of Helsinki and the study was approved by the local ethics committee. The experiment was conducted at Koelliker Hospital in Turin, in collaboration with the Department of Psychology, University of Turin.

5.3.2 Assessment

In a pre-experimental session, we distributed a set of tests to collect data about participants. These tests were selected looking at previous literature in affective neuroscience in order to exclude participants who obtained scores significantly different from the mean:

1) the *Eysenck Personality Inventory (EPI)* (Eysenck & Eysenck, 1990) is a questionnaire adapted in its Italian version from the Eysenck Personality Questionnare (EPQ) (Eysenck & Eysenck, 1975). It was used to assess personality traits and is composed of 69 items. It measures 3 personality traits; psychoticism, extroversion and neuroticism.

2) the *Beck Depression Inventory-II (BDI-II)* (Sica & Ghisi, 2007) was used to exclude depressed participants. It is a questionnaire composed of 21 items, each of which presents 4 sentences from which the subject has to choose the sentence that best describes their mood in the last two weeks.

3) the *Mini Mental State Examination (MMSE)* (Magni, Binetti, bianchetti, Rozzini, & Trabucchi, 1996) is a useful screening test that evaluates principle cognitive functions. It was used to avoid the presence of overt psychiatric or neurological illness.

4) the *Edinburgh Handedness Inventory* (Oldfield, 1971) is a questionnaire that presents to the subject 12 daily actions; asking them to say which hand they would normally use to perform it. It was administered to assess participants' handedness: all of them proved to be right handed.

In order to collect data about emotional state and to measure well-being, the following questionnaires were also distributed to subjects in this session:

1) *Satisfaction with Life Scale* (SWLS, Diener, Emmons, Larsen, & Griffin, 1985).

This takes the form of a questionnaire composed of 5 items, in which the subject must choose the degree of agreement (from 0 to 7 where 0 is "strongly disagree" and 7 is "strongly agree") with each affirmation. This gives a measure of both hedonic and eudaimonic well-being and investigates how close the life of the subject is their ideals, whether or not the condition of his life is excellent, whether the subject is satisfied with their life, how far the subject has come in gaining the important things they want in life and given the opportunity to live life over, whether or not they would change anything.

2) *Questionnaire of Eudaimonic Well-Being* (QEWB, Waterman et al., 2010),

In this questionnaire composed of 5 items, subjects must choose the degree of agreement (from 0 to 4 where 0 is “strongly disagree” and 4 is “strongly agree”) with each affirmation. Affirmations are about how the subject perceives his life with general consideration as to how it is truly going and not to how the subject wishes. The questionnaire gives a measure of eudaimonic well-being, evaluating self-discovery, the perceived development of one’s potential, sense of purpose and meaning in life, pursuit of excellence, involvement in activities and the enjoyment of activities by means of personally expression.

3) *Positive and Negative Affect Scales (PANAS)*, (Terracciano, McCrae, & Costa, 2003),

This questionnaire gives a measure of hedonic well-being and consists of 20 words describing different feelings and emotions (10 are positive and 10 are negative). The subjects have to list for each word a number (from 1 to 5, were 1 is “very slightly or not at all” and 5 is “extremely”) corresponding with how they usually feel.

5.3.3 Stimuli

To describe the events that the subjects had to imagine we composed written scripts. They had a predetermined structure, written in the second person, present tense and described the four phenomenal characteristics of each event.

In each script were described:

Sensorial details - what the subject could see, hear, touch, smell or taste;

Emotional feelings - what the subject could feel and think at the emotional level;

Interoceptive activations - what the subject could feel at a physiological and visceral level;

Movements - movements and behavioural actions made or not made during the event.

The scripts were prepared basing on a pilot study (Sotgiu, Viganò, & Suardi, 2014) in which a questionnaire was administered to 190 students to collect data about relevant hedonic and eudaimonic happy memories. This questionnaire invited half of the participants to freely write down as precisely as possible a eudaimonic event, while the other half had to freely describe as precisely as possible a hedonic event. (Sotgiu, Viganò, & Suardi, 2014). We categorised each event into 19 categories. In doing this we consider the best-described events in each of the two conditions. We extracted 6 categories of hedonic events (HE) (experiences with friends, experiences with relatives, romantic experiences, sexual experiences, attending art or sport exhibitions, travelling) and 6 categories of eudaimonic events (EU) (school achievements, sport achievements, work experience, experiences of autonomy, expression of one's own artistic abilities, helping others). Interestingly, considering the written descriptions of events reported by students we found that most reports followed a structure including the four relevant aspects of a recall (sensorial details, emotional feelings, interoceptive activations, movements).

To control the level of activation of motor areas during the imagination of events, we characterised half the events in each condition (HE, EU, NE) with low amounts of movements. This meant that the script guided the subject to imagine an event in which they were making few or zero motor actions. The remaining half were characterised by a high amount of movement. This meant that the script guided the subject to imagine an event in which they were making many motor actions. This aspect was clearly detailed in the "movements" section of the script and was also based on descriptions collected from the questionnaires administered to students (see Table 5.1 for examples).

Table 5.1 Example of event script

Example of Hedonic Low Motor Activation Event

Your last trip abroad
You're going abroad, to a country you've wanted to visit for a long time. Right now, you are standing still in front of an incredible landscape. Admiring it, you feel the sun warming your face and the wind against your skin. You are aware of a smile forming on your face and in that moment, you experience a feeling of bliss.

Example of Hedonic High Motor Activation Event

A good party with friends

Tonight you've been invited to a party: all your best friends are there, but also some new people that look interesting. You dance and let yourself go, you hear the music and see all your friends laughing and joking. You're really enjoying it and want to enjoy every moment of the party. At this thought, your heart accelerates its beat.

Example of Eudaimonc Low Motor Activation Event

Your degree

It is the day of your graduation. You're standing still, you just finished discussing your thesis and you did a good job. You see some of the teachers who accompanied you during these years. Your cheeks are burning. In this moment, in front of everyone, you realize to be at the end of an important path. You feel satisfied of all you did to reach this point and you realize to be happy.

Example of Eudaimonc High Motor Activation Event

The beginning of a new job

You're on your way to a new job. You walk quickly so that you're on time. You look around at the road that you will be walking every day. Your heart beats quickly. You are curious to know what awaits you, how your colleagues will be and what tasks you'll have to do. You are happy for the start of this new job that you have wanted for a long time.

Example of Neutral Low Motor Activation Event

Going to work by car

Like most mornings, you're going to work by car. Your car radio is on, you're sitting, you feel quiet and anything is unusual in your body. You pay attention to the road while driving and thinking about the various commitments of the day.

Example of Neutral High Motor Activation Event

Taking a shower

You're taking a shower: you feel that your body is wet, you smell bubble bath and you hear the sound of water flowing on your body. You move to soap and rinse yourself while you think back to your day. Your breathing is normal and you're quiet.

For each category of events in each condition were thus created 4 different plausible events; a total of 24 eudaimonic and 24 hedonic events. Following the same procedure, 24 paired neutral events (NE) were created which described daily activities such as cooking dinner, having breakfast, going to work, and so on (see Table 5.2).

Table 5.2 Titles of created events.

LMA	HMA
Eudaimonic	*Eudaimonic*
Admission to a new university course	Passing an important oral examination
My degree	Recognition in school
Getting onto a sports team	Winning a sports competition
The award ceremony in a sports competition	Celebrating victory with teammates
The recognition of my professional value	The conclusion of a particularly useful internship
The achievement of a promotion	Starting a new job
Living independently for the first time	Find a home with my partner
My first pay check	The organisation of a cultural event
The recognition of my artistic skills	A public artistic performance
The satisfaction of expressing my art	The expression of my artistic passion
Making a person close to me happy	Helping a friend to perform a task
A volunteering experience	Organising a charity event
Hedonic	*Hedonic*
Shopping with a close friend	A beach holiday with friends
A memorable afternoon with friends	A good party with friends
An afternoon playing with my nephew	Grandmother's birthday party
A meal with my family	Brother's wedding
The beginning of a new relationship	The first kiss with the person I love
A particularly romantic evening	A romantic bike ride
An unforgettable orgasm	A kiss at the disco
First sexual intercourse with a new partner	Sexual intercourse with a person I met recently
Watching a beautiful film	The concert of a band that I love
Watching my favorite sport on tv	A winning game for my favourite team
My last trip abroad	My first trip alone abroad
The holiday abroad which I had wanted to go on for a long time	Making new friends during a trip abroad
Neutral	*Neutral*
Going to work by car	Going to work on foot
Going to work by bus	Going to work by bike
Heating up lunch in the microwave	Cooking lunch
Waiting for dinner to be ready	Cooking dinner
Watch the news	Cleaning up your kitchen
Channel surfing	Tidying my room
Buying bread	Doing grocery shopping
Having breakfast	Getting ready for work
Checking email	Mowing the lawn
Reading the newspaper	Going upstairs
Waiting for the bus	Taking a shower
Making a phone call to make an appointment	Going to the ATM to withdraw money

Note:LMA=Low Motor Activation; HMA=High Motor Activation

We thus extracted 4 detailed sentences from each created script. One sentence described the sensorial details, one described the emotional feelings, one the interoceptive activations and the last the movements made. All of these short sentences were used as stimuli and the subject had to imagine what the sentences described. Every sentence started with the title of the event followed by a colon and a detailed sentence. The first person was used to increase the emotional impact during the imagination of events (Vella, & Moulds, 2014). The sentences were presented in blocks of four that were more precisely described in the section regarding the experimental session (see Table 5.3 for examples). Lists of event, scripts and sentences were presented in Italian language. They are translated here to give examples. In Appendix A all used scripts are presented in Italian language.

Table 5.3 Example of detailed extracted sentences

Sensorial details
My last trip abroad: I see the landscape, I feel the sun warming my face and the wind against my skin
Interoception
My last trip abroad: I am aware of a smile forming on my face
Emotional feelings
My last trip abroad: I experience a feeling of bliss
Movements
My last trip abroad: I am standing still
Sensorial details
The beginning of a new job: I am on my way to a new job and I look around at the road
Interoception
The beginning of a new job: my heart beats quickly
Emotional feelings
The beginning of a new job: I am curious to know what awaits me
Movements
The beginning of a new job: I am walking quickly

5.3.4 Procedure

5.3.4.1 Pre-experimental session

The pre-experimental session was conducted a week before the experiment. During this session the list of 12 hedonic events with low motor activations (LMA) (Table 5.2) was presented to each participant. Of these, each subject had to choose the four that would have been more pleasant, enjoyable, funny or relaxing if they happened in that moment. We found that four was the ideal number to collect enough fMRI registrations to make statistical contrasts. Every participant then had to make the same choice within the 12 hedonic events with high motor activations (HMA). In the same way they had to choose, within the eudaimonic list, the 4 LMA and the 4 HMA events that, whether happened in that moment, that would have allowed them to feel eudaimonic happiness. It means that they would have experienced to be involved in doing what they believe in, using the best in themselves, pursuing excellence or a personal ideal, developing a skill or a piece of knowledge, or gaining insight into something. These hedonic and eudaimonic definitions were used to explain to the subjects the difference between the two conditions of happiness as adapted from HEMA scale (Huta & Ryan, 2010) as Henderson, Knight and Richardson (2013) did. Finally, with the same procedure, participants were asked to choose 4 LMA and 4 HMA neutral events neither happy nor unhappy for the subject.

Therefore, each participant chose in total 24 different events: 8 HE (4 LMA, 4HMA), 8 EU (4 LMA, 4 HMA), 8 NE (4 LMA, 4 HMA). For each of the selected events participant were then asked (knowing only the title of events and not extended scripts) whether such an event has yet happened in his/her life. This was necessary to collect information about the extent to which subjects could have linked imagined events to their personal past and to control differences of this type across contrasted conditions.

5.3.4.2 Experimental session

The extended scripts of the chosen events were given to each participant directly before the beginning of the experimental session. Alone in a separate room, each participant was asked to take the time needed to read the scripts properly and to try to put themselves in each event as though it was really happening in that moment. Specifically, subjects were asked to imagine the described event was happening currently, and not a similar personal event that had already come to pass in their life. This session ended when the participant read and put themselves in all given scripts.

During the experimental session the total of 96 stimulus sentences, extracted from the chosen events were shown on a screen to each subject in blocks of four for a total of 24 blocks. Sentences of the same condition (HE, EU, NE), same level of motor activation (LMA, HMA), and same aspect of event (sensorial, emotional, interoceptive, movements) were contained in each block. See Tab. 5.4 for a sample block.

Tab. 5.4 Example of one block: hedonic, low motor activation, sensorial details

Shopping with a close friend: looking at the shop window, we talk about exhibits
An afternoon playing with my nephew: I look at her happy face and I see him laughing
The beginning of a new relationship: in front of a nice view, I'm holding his hand
My last trip abroad: I see the landscape, I feel the sun on my face and the wind on my skin

The order of events within a block, much like the order of blocks during the experimental session, was randomised. Each sentence lasted for 5 seconds on the screen and was followed by 2 seconds of a blank screen. After the blank screen, another sentence was presented. At the end of each block, the blank screen lasted for 4 seconds before a new block was presented.

Participants laid flat in the scanner and an adjustable padded headrest was used to keep head movements to a minimum. A colour LCD screen projected the visual stimuli onto a rear projection screen in the bore of the magnet. Participants viewed the screen via an angled mirror system. A computer then ran a psychopy-controlled stimulus presentation.

5.4 Statistical analyses

5.4.1 Statistical analyses for event selection

Statistical analyses were conducted with the Statistical Package for Social Sciences software version 17.0.

Non-parametric tests (Friedman's ANOVA, followed by Wilcoxon tests) were used to analyse whether the quantity of events occurred in particpants' life had been different across the three conditions.

Correlations between the amount of occurred events and demographical and behavioural characteristics of the sample were assessed with Spearman's Rho correlation test.

5.4.2 fMRI data acquisition

Data acquisition was performed with a 1.5 Tesla INTERA™ scanner (Philips Medical Systems) with a SENSE high-field, high-resolution (MRIDC) head coil that was optimised for functional imaging. The functional T2*-weighted images were acquired using echoplanar (EPI) sequences, with a repetition time (TR) of 2000 ms, an echo time (TE) of 50 ms, and a 90° flip angle. The acquisition matrix was 64×64, and the field of view (FoV) 200mm. A total of 200 volumes were acquired; each volume consisted of 19 axial slices, parallel to the anterior-posterior (AC-PC) commissure line and covering the whole brain; slice thickness was 4.5 mm with a 0.5 mm gap. Two scans were added at the beginning of the functional scanning session and the data discarded to reach a steady-state magnetisation before acquiring the experimental data.

In the same session, a set of three-dimensional high-resolution T_1-weighted structural images was acquired for each participant. This data-set was acquired using a Fast Field Echo (FFE) sequence, with a repetition time (TR) of 25 ms, ultra-short echo time (TE), and a 30° flip angle. The acquisition matrix was 256×256, and the field of view (FoV) 256 mm. The set consisted of 160 contiguous sagittal images covering the whole brain. In-plane resolution was 1×1 mm and slice thickness 1 mm (1×1×1 mm voxels).

5.4.3 Data analysis

Functional MRI data were preprocessed using FEAT (FMRI Expert Analysis Tool) Version 5.98, part of FSL (FMRIB's Software Library, www.fmrib.ox.ac.uk/fsl). This included skull extraction, slice-timing correction, bulk head-motion correction, spatial smoothing (Gaussian kernel of full-width-half-maximum 5mmfor slow fMRI and 6mmfor fast fMRI), and a high-pass (150 s) temporal filter. All participants maintained peak-to-peak head motion_3mm for all scans.

5.4.4 Voxelwise univariate statistical analysis

First-level analyses were carried out for each subject to compute the contrast of interest. Subsequently we submitted these contrasts to a higher level random effects General Linear Model (GLM) analysis using FSL FMRIB's.

The analysis was performed using a random effects General Linear Model (RFX), with 'subject' as the random variable. A design matrix was created, using a predictor for each condition. The predicted time course was adjusted for the typical hemodynamic response delay by convolution with a canonical (double gamma) hemodynamic response function. Statistical contrasts were considered at the multi-subject whole-brain level, FDR corrected at q=0.05.

5.5 Results

5.5.1 Event selection

Looking at event selection made by subjects, we noted the most commonly chosen events (considering events chosen by at least 8 participants) (see table 5.5 for data.). Within the eudaimonic condition, the most-chosen events were: “My degree”, “The recognition of my professional value”, “Living independently for the first time”, “Making a person close to me happy” (LMA) and “Passing an important oral examination”, “Recognition in schools”, “Starting a new job”, “Help a friend to perform a task” (HMA).

Within the hedonic condition, they were instead: “A memorable afternoon with friends”, “An unforgettable orgasm”, “The holiday abroad which I had wanted to go on for a long time” (LMA) and “A beach holiday with friends”, “A good party with friends”, “The first kiss with the person I love”, “My first trip alone abroad”, “Making new friends during a trip abroad” (HMA).

Finally, within the neutral condition they included: “Channel surfing”, “Waiting for the bus” (LMA) and “Doing grocery shopping”, “Going upstairs”, “Go to the ATM to withdraw money” (HMA).

Table 5.5 Events ordered on the number of subject that chose each of them within different sets of events

LMA		HMA	
Eudaimonic		*Eudaimonic*	
Making a person close to me happy	*14*	Passing an important oral examination	*11*
My degree	*13*	Recognition in school	*9*
Living independently for the first time	*11*	Starting a new job	*9*
The recognition of my professional value	*9*	Helping a friend to perform a task	*9*
Admission to a new university course	*4*	Find a home with my partner	*6*
The achievement of a promotion	*4*	Winning a sports competition	*5*
My first pay check	*3*	A public artistic performance	*5*
The satisfaction of expressing my art	*3*	Organising a charity event	*5*
A volunteering experience	*3*	The expression of my artistic passion	*4*
The award ceremony in a sports competition	*2*	The organisation of a cultural event	*3*
The recognition of my artistic skills	*2*	The conclusion of a particularly useful internship	*2*
Getting onto a sports team	*0*	Celebrating victory with teammates	*0*
Hedonic		*Hedonic*	
The holiday abroad which I had wanted to go on for a long time	*15*	The first kiss with the person I love	*12*
A memorable afternoon with friends	*10*	A beach holiday with friends	*10*
An unforgettable orgasm	*8*	My first trip alone abroad	*9*
A particularly romantic evening	*7*	Making new friends during a trip abroad	*9*
Watching a beautiful film	*7*	A good party with friends	*8*
My last trip abroad	*6*	The concert of a band that I love	*6*
A meal with my family	*5*	A romantic bike ride	*4*
First sexual intercourse with a new partner	*4*	Sexual intercourse with a person I met recently	*4*
An afternoon playing with my nephew	*3*	Brother’s wedding	*2*
The beginning of a new relationship	*2*	A kiss at the disco	*2*
Watching my favorite sport on tv	*1*	Grandmother’s birthday party	*1*
Shopping with a close friend	*0*	A winning game for my favourite team	*1*
Neutral		*Neutral*	
Waiting for the bus	*10*	Going upstairs	*12*
Channel surfing	*9*	Doing grocery shopping	*11*
Heating up lunch in the microwave	*7*	Going to the ATM to withdraw money	*11*
Having breakfast	*7*	Getting ready for work	*7*
Buying bread	*6*	Taking a shower	*7*

Reading the newspaper	*6*	Going to work on foot	*4*
Watch the news	*5*	Cooking lunch	*4*
Checking email	*5*	Mowing the lawn	*4*
Going to work by car	*4*	Cleaning up your kitchen	*3*
Waiting for dinner to be ready	*4*	Going to work by bike	*2*
Going to work by bus	*3*	Tidying my room	*2*
Making a phone call to make an appointment	*2*	Cooking dinner	*1*

Note: LMA=Low Motor Activation; HMA=High Motor Activation

Outlined in Table 5.5 are the percentages of events which had and had not occurred in participants' life. As mentioned before, these data were collected by asking participants to declare after their choice of each event whether or not a similar event had ever occurred in their life so far.

Table 5.5 Percentages of occurred or not occurred events within each condition.

	Eudaimonic		Hedonic		Neutral		Total	
	Occurred	Not occurred	Occurred	Not occurred	Occurred	Not occurred	Occurred	Not occurred
Mean	63.23%	36.77%	80.88%	19.12%	93.38%	6.62%	80.39%	19.61%

Friedman's ANOVA analysis showed significant differences in the amount of events which had occured across the three conditions (χ^2=15.094, p=.001). Subsequent Wilcoxon signed rank tests (with Bonferroni correction) indicated that number of occurred events was fairly lower in the eudaimonic condition respect to both the hedonic (z=-2.550, p=.011) and neutral (z=-3.132, p=.002) conditions, while in the hedonic condition it was still significantly different from the number of occurred events in the neutral condition (z=-2.488, p=.013). In total, the number of occurred events within the total events chosen by participants was greater than the number of those which had not occurred (z=-3.550, p<.001).

Analyses of correlations showed that the total number of occurred events had a correlation with age (ρ=.866, p<.001) and schooling (ρ=.686, p=.002). These correlations were also found when looking at the number of the occurred events in the eudaimonic condition: age (ρ=.824, p<.001), schooling (ρ=.627, p=.007). Similar patterns were present in the hedonic condition: age (ρ=.757, p<.001), schooling (ρ=.722, p=.001). None correlation was found between age, schooling and quantity of occurred events in the neutral condition. Significantly, none notable correlation was found between the amount of occurred events (in total and across conditions) and any other demographic and neuropsychological characteristics of the sample, personality traits or well-being measures.

5.5.2 Assessment

In Table 5.6, demographic characteristics of the sample and means of neuropsychological characteristics, well-being measures and personality traits assessments are presented. Mean scores resulted comparable to ones obtained in previous validation studies (Diener et al., 1985; Eysenck & Eysenck, 1990; Magni et al., 1996; Oldfield, 1971; Sica & Ghisi, 2007; Terracciano et al., 2003; Watermann et al., 2010). The sample resulted to have a high degree of education (most participants were universitary students); all participants resulted to be right-handed; MMSE revealed a normal neurological functioning; BDI detected a low level of depressive symptoms. None personal traits emerged as out of normative standard means from EPI; even well-being measures were in line with normative standard means.

Table 5.6 Demographic, neuropsychological and personal characteristics and well-being measures of participants' sample

	Mean	Std. Deviation
ED	14.41	2.78
AGE	25.24	4.94
MMSE	29.47	.71
BDI	4.47	4.74
EPI_P	5.00	2.17
EPI_E	13.53	3.44
EPI_N	10.53	4.79
OLDFIELD	11.06	1.08
SWLS_t	23.94	3.69
QEWB_t	55.88	11.16
Positive Affect	33.23	5.05
Negative Affect	19.88	6.19
Hedonic balance	13.35	7.98

Note: ED= years of education; MMSE= Mini Mental State Examination; BDI= Beck Depression Inventory; EPI_P= Eysenck Personality Inventory, Psychoticism; EPI_E= Eysenck Personality Inventory, Extroversion; EPI_N= Eysenck Personality Inventory, Neuroticism; SWLS_t= Satisfaction Whit Life Scale, total; QEWB_t= Questionnaire of Eudaimonic Well-Being, total.

5.5.3 fMRI results

Table 5.7 shows the results of contrasts between happy conditions (hedonic and eudaimonic) and neutral condition. When the brain activity associated with neutral condition was subtracted from them associated with eudaimonic condition, BOLD signal increases encompassing frontal, temporal and parietal regions, but also subcortical regions and the posterior right cerebellum was detected. Peaks of clusters were located in the left frontal inferior orbital gyrus and right cingulate gyrus within the frontal lobe. Also, a large cluster showed a peak of increased BOLD signal in the left middle temporal pole with significant activations in the left insula. Other clusters encompassed the left hippocampus, left amygdala and left putamen, having a peak of activation located in the left parahippocampal gyrus. Finally, other peaks of intensity of BOLD signals were found in the right hippocampus, right inferior occipital gyrus and right occipital superior gyrus. When the neutral activity was subtracted from the hedonic condition, significant BOLD signal increases were detected, showing peaks located in the left middle frontal gyrus, left medial frontal gyrus, right PCC, right supplementar motor area (SMA), left middle temporal gyrus, left temporal inferior gyrus, right fusiform gyrus and left precuneus. A large cluster, encompassing subcortical activations within the right amygdala, right hippocampus, right thalamus and right globus pallidus, was present, having its peak of intensity in the right posterior cerebellum.

Conversely, when the activation linked to eudaimonic condition was subtracted from neutral condition significant BOLD signal increases were noted in the right IPL, while when activation linked to the hedonic condition was subtracted from neutral condition, increases of BOLD signal were detected in the right Heschl's gyrus, left precuneus and left precentral gyrus (PrCG). See Fig. 5.1 for Eudaimonic vs Neutral and Hedonic vs Neutral comparisions.

Contrasting the two happiness conditions directly (Table 5.8), when the hedonic condition was subtracted from the eudaimonic condition significant BOLD signal increase was noted in the right PrCG, while subtracting eudaimonic condition from the hedonic condition led to significant BOLD signal increases noted in the right medial frontal gyrus, right middle frontal gyrus, left superior medial frontal gyrus and left ACC. See Fig. 5.2 for Hedonic vs Eudaimonic comparision.

In Appendix B all clusters of activation across different conditions are presented.

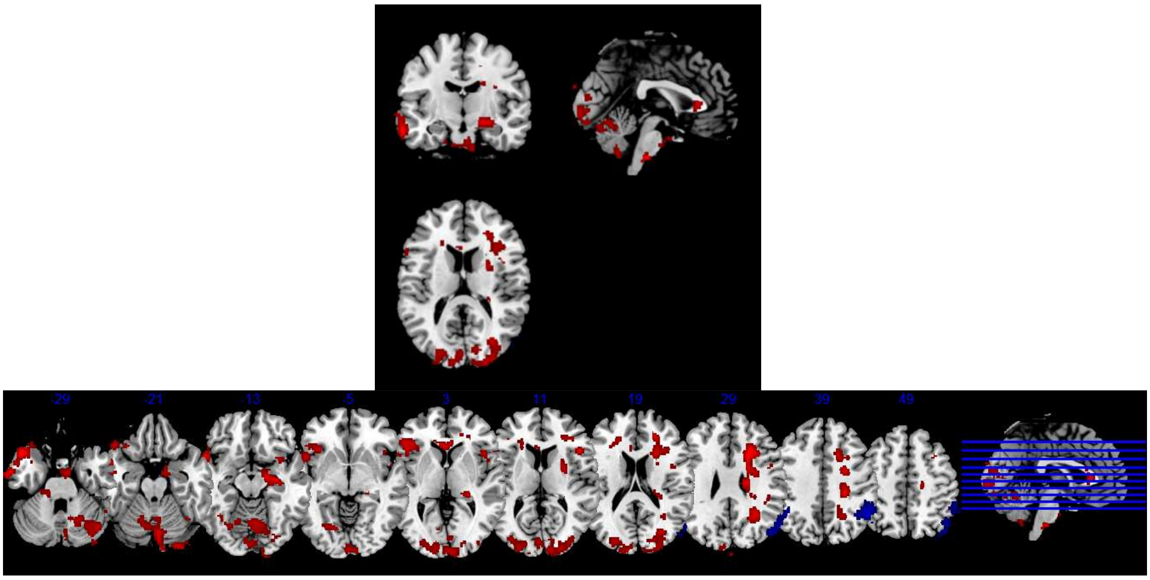
Table 5.7 Results of Eudaimonic vs Neutral, Hedonic vs Neutral, Neutral vs Eudaimonic, Neutral vs Hedonic contrasts. Significant peaks of activation within each contrast, brain side, number of voxel (2x2x2 mm^3) in the peak, MNI coordinates and z-scores are reported

Region	Side	N° voxel	X	Y	Z	Z-score
Main effect of Eudaimonic > Neutral						
Frontal Inferior Orbital Gyrus	L	63	-48	26	-18	2.9
Cingulate Gyrus	R	2652	22	14	30	3.7
Middle Temporal Pole	L	2119	-42	16	-36	4.7
Insula	L	73	-42	16	-36	4.7
Parahippocampal Gyrus	L	72	-18	-16	-34	3.2
Hippocampus	R	469	28	-14	-12	3.3
Amygdala	R	18	28	-14	-12	3.3
Putamen	R	6	28	-14	-12	3.3
Inferior Occipital Gyrus	R	158	42	-86	-24	2.9
Occipital Superior Gyrus	R	1773	30	-76	18	2.9
Posterior Cerebellum	R	1693	28	-58	-44	3.9
Main effect of Hedonic > Neutral						
Middle Frontal Gyrus	L	44	-38	6	68	2.3
Medial Frontal Gyrus	L	7645	-8	52	52	5.4
Posterior Cingulate	R	384	8	-34	22	3.4
Supplementary Motor Area	R	194	6	16	76	3.0
Middle Temporal Gyrus	L	2750	-42	20	-34	4.9
Temporal Inferior Gyrus	L	45	-32	2	-42	2.6
Fusiform Gyrus	R	1689	22	10	-42	4.2
Precuneus	L	629	-2	-60	30	3.2
Posterior Cerebellum	R	7626	40	-72	-56	4.3
Hippocampus	R	138	40	-72	-56	4.3
Thalamus	R	28	40	-72	-56	4.3
Amygdala	R	10	40	-72	-56	4.3
Globus Pallidus	R	10	40	-72	-56	4.3
Main effect of Neutral > Eudaimonic						
Inferior Parietal Lobule	R	1418	54	-54	38	3.7
Main effect of Neutral > Hedonic						
Heschl's Gyrus	R	6204	40	-28	16	3.9
Precuneus	L	137	-12	-70	52	2.8
Precentral Gyrus	L	197	-30	-18	60	3.7

Note: the direction of contrast (e.g. Eudaimonic > Neutral) means that the reported areas are the ones resulted to be more active when the second condition is subtracted from the first (e.g. when neutral condition is subtracted from eudaimonic condition)

Fig. 5.1 Brain activations related to eudaimonic and hedonic condition, contrasted to neutral condition. The results are reported in coronal, axial, and sagittal slice and then in multiple axial slices.

Eudaimonic condition
Red= eudaimonic minus neutral
Blue=neutral minus eudaimonic



Hedonic condition
Red= hedonic minus neutral
Blue=neutral minus hedonic

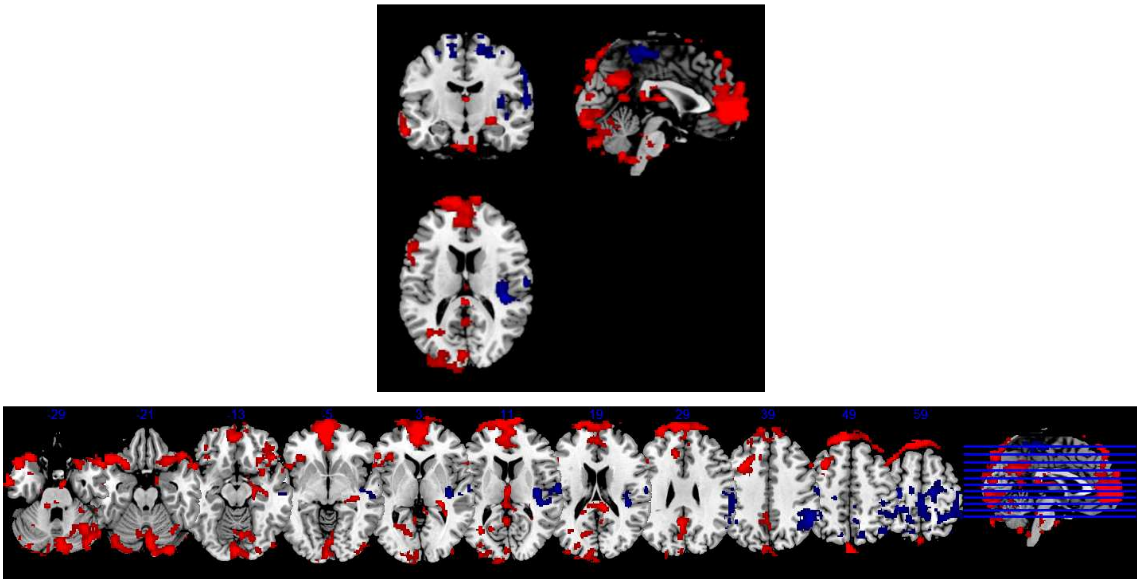
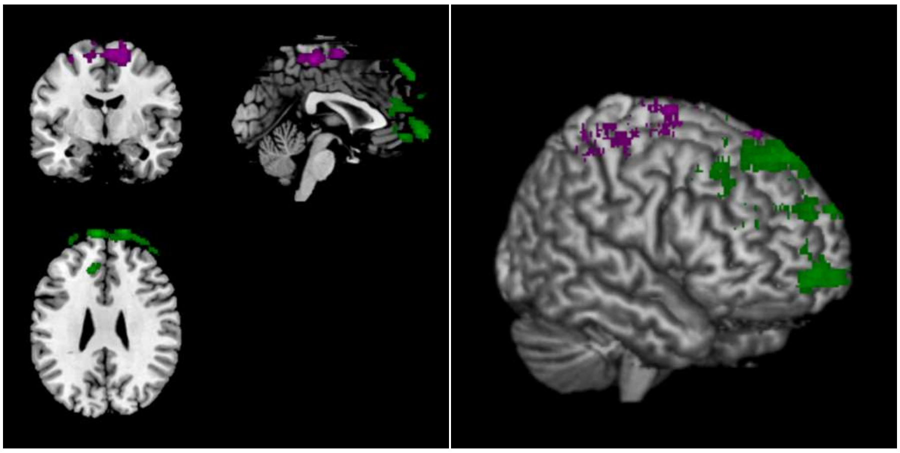


Table 5.8 Results of Eudaimonic vs Hedonic, Hedonic vs Eudaimonic contrasts. Significant peaks of activations within each contrast, brain side, number of voxel (2x2x2 mm³) in the peak, MNI coordinates and z-scores are reported

Region	Side	N° voxel	X	Y	Z	Z-score
Main effect of Eudaimonic > Hedonic						
Precentral gyrus	R	3816	16	-26	64	3.7
Main effect of Hedonic > Eudaimonic						
Medial Frontal Gyrus	R	1303	-4	72	-8	3.3
Middle Frontal Gyrus	R	1898	12	50	54	3.7
Superior Medial Frontal Gyrus	L	182	-8	68	28	3.4
Anterior Cingulate	L	87	-12	34	30	3.2

Note: the direction of contrast (e.g. Eudaimonic > Hedonic) means that the reported areas are the ones resulted to be more active when the second condition is subtracted from the first (e.g. when hedonic condition is subtracted from eudaimonic condition)

Fig. 5.2 Brain activations resulted from the contrast *eudaimonic minus hedonic* (violet) and *hedonic minus eudaimonic* (green) conditions.



CHAPTER 6: DISCUSSION AND CONCLUSIONS

6.1 Discussion

In this chapter we first discuss the results of analyses regarding event selection. In the second section we will discuss the results of fMRI analyses. We will then conclude, summarise findings from this study, discussing limitations and attempting to suggest future research directions.

6.1.1 Event selection

When considering the most chosen events, noticeable immediately is a conceptual difference between the eudaimonic and the hedonic events.

It seems that the majority of frequently chosen eudaimonic events (except for making happy a dear person and help a friend to perform a task) are events that usually happen only once or rarely in an ideal timelife (“My degree”, “The recognition of my professional value”, “The beginning of an independent life in my house”, “Passing an important oral examination”, “Recognition in schools”, “The beginning of a new job”). Conversely, the most commonly selected hedonic events (except perhaps for “The first kiss with the person I love”, “My first trip alone abroad”) may be considered as events that could happen more than once in a lifetime (i.e. “An unforgettable afternoon with friends”, “An unforgettable orgasm”, “The holiday abroad wished a long time”, “The beach holiday with friends”, “A good party with friends”, “I make new friends during a trip abroad”). Worthy of note is that this observation is valid for most chosen events yet not for all proposed events. In both conditions either events that usually happen once in a lifetime or repeatable events were proposed. This difference, in terms of the chance of repeatability of the chosen events, gets stronger when we look at neutral events. Most of the chosen events are daily activities that could possibly happen many times every day. An interpretation of these differences could be found in the concept of hedonic and eudaimonic happiness; the oncept of eudaimonic happiness refers to self-realisation and participants tend to choose events that represent life goals or change of status. These are less frequent than others. Inversely, the concept of hedonic happiness presumes the enjoyment of significant but repeatable events; neutral events are experiences to which the subject has become habituated and can change them somewhat.

This could explain the difference observed in the amount of occurred events across the three conditions. Neutral events were found to be those which had occurred most frequently while hedonic events slightly less so because they represent special but not unique events. Eudaimonic is the condition in which the greatest number of events had not already happened to participants.

Considering correlations with personal characteristics of the participants, we found that the amount of events which have already occurred increases in correlation with the age of participants; showing significant correlations both in the eudaimonic and hedonic conditions, yet not in the neutral condition.

This seems fairly logical; the older the subjects are the more experiences they are likely to have lived and thus more eudaimonic and hedonic events are likely to have occurred in their life. Considering the ease of occurrence of neutral events, it is clear that almost all of these events had already happened in participants' life. In eudaimonic and hedonic conditions, the same pattern of correlation was found between the number of events which had already occurred and years of education. This result could be explained by considering that these events were modelled on the basis of questionnaires administered to a large sample of students. As such, they are typical events dreamed about or considered "happiest" in a student's life. More education means more years spent by the subject as a student and more chances to reach goals typical of a student life (e.g: obtaining a degree). We would likely have found a different number of already-occurred events in a sample mostly composed by working people of the same age.

These considerations reassure us that the set of created events were correctly designed around the features of the participant sample.

Furthermore, the significantly different number of events which had already occurred across the three conditions, needs to be taken in consideration when we look at the patterns of activations found during fMRI scanning. We can claim that it did not drive differences found in BOLD signals by means of emphasising the fact that the experiment required to the subject to imagine an event with defined features and a defined storyline, explicated in the extended scripts that the subject read before the scanning section (with the help of sentences extracted from this script as reminder). Each subject had also clear instructions asking them to imagine that the event described in the script was happening presently and to not drawn from a similar event which had already happened to them.

Considering of course that events similar to the proposed ones could have occurred most frequently in neutral condition first, then in hedonic and finally in eudaimonic conditions, we could expect differences in the participation of regions traditionally thought to be responsible for memory recall and event construction and thus for mental time travel, across different conditions.

6.1.2 fMRI contrasts

The aim of fMRI scanning was to compare eudaimonic and hedonic conditions in order to explore neural correlates and investigate whether or not the theoretical and psychological distinction between these two aspects is corroborated by distinction in neural correlates. To achieve this, we directly compared the two conditions. To separate happiness activations from events construction activations we first subtracted neutral condition (which does not imply emotional activations) from the two happiness conditions.

Results showed that in the eudaimonic and in hedonic conditions, in contrast to the neutral condition, the imagination of happy events and the emotion related to this mental travel activated similar patterns in both conditions, particularly linked to the frontal, temporal, parietal and subcortical activations.

These activations were slightly different when looking separately at the two contrasts (eudaimonic vs neutral and hedonic vs neutral), but these differences were not great enough to become significant in the direct contrast (eudaimonic vs hedonic). However, we consider them interesting and worthy of further discussion.

Starting with frontal activations, we can observe that imagining eudaimonic events in respect to neutral events engages the OFC that was described as being involved with the reward system in the process of reward valuation and expectations that the reward implies (Doya, 2008), much like when monitoring reward value (Kringelbach, 2005). Conversely, imagining hedonic events seems to involve the medial and middle parts of the frontal gyrus more than in respect to neutral events. It is necessary to remember that mPFC is strongly related to the self. It codes for self-referential processing, self-reflective thoughts and is strongly connected with the amygdala and hippocampus. It is also a key region of the mental time travel ability as well as the Brain's Default Network. The middle frontal gyrus, also called the dlPFC is a "control" region, and as such there is implied the attentional monitoring of relevant stimulus and responsible of goal representations (Fareri & Delgado, 2013). It also guides planned behavioural actions (Miller & Cohen, 2001), plays a role in controlling preparation and online emotion regulation (Ochsner, Bunge, Gross, & Gabrieli, 2002; Seo et al., 2014) and in depressed patients it seems to be the region related to self-evaluation (Sperduti et al., 2013). We must note that all the above-cited activations within the frontal lobe appear in the left side of the brain.

Furthermore, both happiness conditions, in contrast to the neutral condition, activated the cingulate cortex (more posteriorly during imagination of hedonic events [PCC]). These activations occurred in the right side. The cingulate cortex is a region involved in attention as well as emotion and the construction of memory. The anterior part of the cingulate cortex (ACC) is involved in the complex aspect of emotion in processing moral emotion, action reinforcements and the evaluation of emotional stimuli. The PCC is a central part of the BDN and is generally involved in emotional episodic construction (Fareri & Delgado, 2013); particularly when associated with activity in the precuneus (as in our experiment) it seems to play a role in the preparatory control of emotion (Seo et al., 2014).

Furthermore, at the boundaries of the frontal region, when the hedonic condition was compared with the neutral condition we found increased BOLD signals in the right SMA. This region, and more generally the right PrCG, was reported to play a crucial role in cognitive reappraisal of goal representation during emotion regulation (Seo et al., 2014). We will discuss this point in more detail below, considering its greater activation when the hedonic condition was directly subtracted from eudaimonic condition.

We thus found consistent increases in BOLD signals within the temporal pole when the neutral condition was subtracted from both happiness conditions. These activations seem to be particularly confined to the left side of the brain in the middle temporal gyrus (MTG). The MTG is traditionally thought to be involved in the processing of semantic material such as storytelling (Bartha, et al. 2003; Steinvorth, Levine, & Corkin, 2005). In more detail, it showed activations together with the left inferior part of temporal lobe, encompassing the left parahippocampal gyrus, and left temporal inferior gyrus. All these regions, with the fusiform gyrus activated during the hedonic condition, are crucial in the recognition of scenery such as landscapes, rooms, and physical locations in general, but also in facial recognition (Epstein &

Kanwisher, 1998) much as happens during the imagination of events that implies the combination of scenarios experienced before.

Again, activations of the right hippocampus were found in the temporal pole during eudaimonic conditions. Studies demonstrated its involvement in spatial memory more than in episodic memory (Burgess, Maguire, & O'Keefe, 2002).

Activations were thus found in the parietal lobe. During the eudaimonic condition compared to the neutral condition we found activations in the right inferior and superior occipital gyrus. Regions found by prior studies (such as the right fusiform gyrus) are involved in the processing of visual stimuli with emotional content (Lang et al., 1998) as with the imagination of events (Addis & Schacter, 2008).

Finally, peaks of activation were found in the posterior cerebellum on the right side. The cerebellum, in addition to having a fundamental role in movement, sensorimotor processes and mental time travel, has been recognised in recent studies as a locus in which primary emotions are processed (Bastian, 2011; Baumann & Mattingley, 2012; Schmahmann, 2010; Stoodley & Schmahmann, 2009). This is also based on the presence of a strong connection with a set of subcortical structures traditionally involved in emotion. These structures include the amygdala, insula, the hypothalamus, septum and basal ganglia, as well as the neocortex and brainstem nuclei (Anand, Malhotra, Singh, & Dua, 1959; Middleton & Strick, 2001; Schmahmann, 2001; Schutter & van Honk, 2005; Snider & Maiti, 1976). Our results in fact indicated activations of both the posterior cerebellum and subcortical regions like the thalamus, right amygdala and basal ganglia as much as the globus pallidus and putamen, previously hypothesised as being involved in happiness and pleasure. This data showed an activation of emotion-related areas as well as pleasure-related structures, during both hedonic and eudaimonic conditions, proving the effectiveness of the used mood induction procedure to elicit happiness but also the similarities between the two concepts of happiness in terms of neural correlates. Both conceptions showed activation of areas dense of opiate receptors that are what we called "hedonic hotspots".

Considered together, these results show the activation of a large number of regions encompassing the left frontal cortex, right cingulate cortex, left temporal lobe and right parietal lobe during the imagination of happy events, compared to the imagination of neutral events. Patterns of activations in both happy conditions look very similar and they involve different processes such as self-referential processes, goal striving, motivation and reward representation, emotional and pleasure reactions, as well as emotional episodic thinking through the processing of verbal material, with some support given by scenarios construction and visual details. All these processes and regions are constituents of the Brain's Default Network (Buckner, Andrews-Hanna, Schacter, 2008; Buckner, 2012) and strongly overlap with neural correlates of mental time travel. This observation could also account (especially considering temporal regions) for the differences found in the number of similar occurred events. The imagination of happy events required more episodic construction than the imagination of neutral events that are more likely to have occurred in a way similar to the described ones.

The imagination of neutral events, compared to both happiness conditions, elicited greater activations of the right IPL (when eudaimonic condition was subtracted) and the left precuneus (when hedonic condition was subtracted). These regions are part of the posterior subsystem of BDN that is typically involved in episodic memory retrieval (Buckner, 2012). Peaks of activations in the neutral vs hedonic conditions were also found in the right heschl's gyrus, strongly connected with the precuneus (Zhang & Li, 2012) and whose role is especially to code for verbal auditory material (see e.g. Pundir et al., 2015). These results can account for a greater retrieval of past similar episodes during the imagination of neutral events with respect to the happiness conditions, but the activation of the auditory cortex could also account for attentional focus on the verbal material and its mental rehearsal when emotional experience is not induced. This hypothesis is supported by the activation of the left PrCG, which is usually involved in motor actions connected to speech (Behroozmand et al., 2015).

The most interesting results regarding the aim of this dissertation come from the contrast between the eudaimonic and hedonic conditions. The significant differences in the increase in BOLD signals appear to be isolated within the frontal lobe. They all overlap with part of the BDN, especially its anterior/frontal subsystem which is attributed to self-referred processes. There are however some key difference. The imagination of hedonic events seems to activate more the medial and middle frontal gyrus and ACC. We already linked all of these areas to self-referential processes, reward representations and tracking history of past rewards and outcomes. The eudaimonic condition showed increases in BOLD signals in a single cluster with a peak in the right PrCG. This region, in addition to being fundamental for motor execution, proved to be one of the differences in the networks related to autobiographical recall and envisioning the future (Szpunar & McDermott, 2007; 2009). Part of its activation could thus be explicated by the intrinsic characteristics of eudaimonic events; they are more likely events which have not occurred and their imagination is more similar to the process of future envisioning than autobiographical recall.

Moreover, this region also plays a crucial role in the control of actions directed to a goal (Christensen et al, 2007; Pastor-Bernier, Tremblay, & Cisek, 2007), in the modulation of motivation and reward (Roesch & Olson, 2003) and has been associated with the greater use of cognitive reappraisal (Leung & Lee, 2012; Seo et al., 2014). It seems that the subject, involved in the imagination of eudaimonic events, should need a cognitive reappraisal of goals and actions planned to reach this goal in order to modulate the reward's representation and motivation linked to that goal.

We thus found differences in neural activities correlated to the imagination of events of the hedonic and eudaimonic kind. It seems that the subjects involved in the imagination of a hedonic event activated areas more related to the self and to the attainment of personally relevant rewards. When the subject is instead invited to imagine eudaimonic events, a cognitive reappraisal is required to plan complex actions to reach a goal and it also becomes necessary to give different meanings to these actions. Two examples to better understand this are as follows. In the hedonic condition, the subject could be invited to imagine a sexual approach; this action is directly considered a reward by the subject and activates cortical regions of the reward system linked to the self, meaning the satisfaction of personally relevant needs and the consequent pleasure. Conversely, in the eudaimonic condition, the subject could be invited to imagine passing an important oral examination; to pass an oral examination the subject has to study and make different actions that could imply some effort. These actions usually do not directly satisfy personal basic needs and some subject may not consider them as pleasant or rewarding. He needs cognitive reappraisal to plan these actions and to consider them as pleasant in light of the final goal that he considers personally relevant.

The found results are quite different from expectations: the only neuroscientific hypotheses specifically proposed about eudaimonic happiness (Berridge & Kringelbach, 2011; Kringelbach Berridge, 2009) stated the possibility of involvement of frontal key regions, dense with opiate receptors, overlapping the BDN as, for instance, OFC, ACC. This is certainly true, because both eudaimonic and hedonic happiness showed activations in these regions compared to the neutral condition, but the peculiarity of eudaimonic happiness seem to arise in an unexpected region as right PrCG is.

The reported differences between hedonic and eudaimonic aspects of happiness during the imagination of future events reflects the distinction between anticipatory and consumatory processes involved in positive affects. Eudaimonia could be represented by goal striving and sense making in anticipation of future reward, while hedonia could be represented by the enjoyment of present rewards. Therefore although one could argue that differences between the two conditions are more related to the different degrees of remembering or envisioning the future, we could also suggest that this is a difference deeply implied in the concepts of eudaimonic and hedonic happiness. We can also claim that these two interpretations can be combined; goal striving and sense making are more likely to require the envisioning of the future while the enjoyment of rewards is more likely linked to past similar actions.

We can conclude that the imagination of happy events activates a core network comprising of frontal, temporal and parietal regions, as well as activations located in cerebellum and subcortical structures as amygdala and basal ganglia. Cortical activations mainly overlap the Brain's Default Network. Within the frontal part of this system we can find two distinct subsystems that reflect the psychological distinction between the two main aspects of happiness. One aspect, hedonic happiness, activates the most frontal medial/middle regions and ACC, associated with rewarding the self. The other aspect, eudaimonic happiness principally activates regions associated with action planning to reach a goal and cognitive reappraisal. We can argue that hedonic happiness makes the subject more involved with themselves and their internal world, while eudaimonic happiness requires cognitive sense-making and commits the subject to the external world. Therefore, we can claim that the two concepts of happiness linked the subjects to opposing perspectives; hedonic to the past and to themselves, eudaimonic to the future and to the external world.

A limitation of this study is represented by the utilisation of events considered purely to be an expression of one of the happiness conditions. Actually, a recent study (Henderson et al., 2013) demonstrated how most of human activities could be at the same time both hedonic and eudaimonic and that each subject could consider one activity (even the neutral ones) more hedonic or more eudaimonic to certain extents. We were aware of this question, but respect to the study of Henderson et al. (2013) that presented general activities to the participants, we proposed events of life to the participants. Events, respect to routinary activities, are more complex, peculiar, and characterised. Moreover, to overcome this question, we created events that the participants had to imagine. As we already described, this methodological precaution was adopted considering that imagined emotions are more pure and easily overestimated than real ones. In fact, real emotions are often contaminated by each other. Furthermore, the set of events had come from the previous pilot study in which participants were asked to describe hedonic or eudaimonic events. Finally, the section entitled "emotional feelings" of the scripts was written to express and maximise the condition of happiness in which the event was included. However, to better explore this question, we trust that subjective ratings of hedonic or eudaimonic happiness felt in each proposed event could be utilised in future research before scanning occurs; allowing the researcher to take into account subjective perceptions and elicit more differences in signal increases under different conditions.

Another limitation of this study was represented by differences in the degree of happened events across conditions. Future studies could minimise this potential difficulty. Considering that we intrerpretated this difference as to be intrinsic between the two concepts of happiness, it could also be interesting to investigate whether or not the same results would be obtained conducting the research on a sample of subjects of different ages. In fact, it is probable that an older subject would have achieved still more life goals and that the imagined events could be more likely to be linked to similar personally occurred events in the past in the same percentage across conditions.

These data need further confirmation due to the small sample size, but further research could be of great interest, particularly in order to better understand pathological states like anxiety or mood disorders, like major depression or bipolar disorders. The knowledge of brain regions involved in hedonic and eudaimonic happiness could aid research focused on their neural correlates in understanding mechanisms of their pathological loss.

In light of recent studies demonstrating the significant reduction in stress level, anxiety and depression in patients involved in prospection and using mental time travel to recall positive events (e.g. Quoidbach, Wood & Hansenne, 2009; Roepke & Seligman, 2015), our results could be useful in designing treatments for these disorders based on mental simulation of different kinds of happy events.

6.2 Conclusions

The aim of this study was the investigation of neural correlates in the imagination of happy events, in order to find distinctive neural patterns reflecting the psychological distinction between hedonic and eudaimonic happiness. The results of fMRI contrasts lead us to believe that, even if both hedonic and eudaimonic happiness are related to similar patterns of brain activation, the two main aspects of happiness are sustained by different neural correlates.

Actually, a core network was activated by the imagination of both eudaimonic and hedonic events, involving the left frontal regions and right cingulate cortex. The activation of these regions accounts for self-referential processes, goal-striving and motivations and rewards representation. The activation of the left temporal regions accounts for emotional episodic construction throughout the processing of verbal material. The activation of the right parietal regions accounts for scenarios' construction and processing visual details. Most of these regions overlap with the Brain's Default Network and the neural basis of mental time travel, demonstrating how imagining happy events is one of the activities in which autonoetic consciousness is involved daily when other cognitive tasks are not performed. During the guided imagination of happy events, with respect to neutral ones, activations were also found located in the posterior cerebellum and subcortical structures such as the hippocampus, amygdala and basal ganglia, accounting for the effectiveness of the novel procedure used to elicit happiness.

Two patterns of activation were found in the two different happiness conditions. During the imagination of hedonic events, the medial and middle frontal gyrus and ACC were activated. These areas are loci of self-referential process; furthermore their activation correlates with history of reward representations and the tracking of past rewards and outcomes. Instead, during the imagination of eudaimonic events, the right precentral gyrus, locus of planned actions and cognitive reappraisal, was activated.

These results give data in favour of distinctive neural patterns correlated to the two happiness concepts. They also make possible further interpretations of the psychological sense of this distinction.

In conclusion, hedonic happiness is an emotion addressed to the self, to the internal world of the individual and his past experiences, directly linked with the rewards' system and enjoyment of basic pleasures. On the contrary, eudaimonic happiness is an emotion adressed to the external world and to the future experiences of the individual. Eudaimonic happiness requires actions and cognitive reappraisal of these actions in order to recognise them as the path to reach a pleasant feeling.

These results are encouraging and can considered the basis of further investigations that take into account participants' subjectivity; in fact, subjectivity is the core of the personal emotional experience that happiness is.

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APPENDIX A: Extended scripts of presented happy and neutral events

LOW MOTOR ACTIVATION

Eudaimonic events

L'ammissione al nuovo corso universitario

Sei a casa tua, sdraiato, in un momento di relax. Senti squillare il tuo cellulare. Lo guardi. Hai ricevuto un SMS da un tuo amico che ti annuncia che hai superato il test di ammissione per il nuovo corso universitario. Il cuore inizia a batterti forte. Ti senti molto orgoglioso di te stesso per questo traguardo, che hai a lungo atteso e per il quale ti sei impegnato a fondo. Sai che è l'inizio di una nuova avventura e di una nuova vita ricca di stimoli.

La tua laurea

E' il giorno della tua laurea. Sei in piedi, fermo, hai appena finito di discutere la tua tesi e la discussione è andata bene. Vedi davanti a te alcuni dei professori che ti hanno accompagnato in questi anni. Le tue guance sono infuocate. In quel momento, davanti a tutti, realizzi di essere alla fine di un percorso importante. Ti senti soddisfatto per tutta la strada che hai fatto e realizzi di essere felice.

Il superamento di una selezione sportiva

Hai appena finito una gara sportiva. Era una gara importante quella di oggi: a vederti c'erano dei selezionatori sportivi che volevano valutarti per prenderti nella loro squadra. La gara ti sembra andata bene e pensi di avere dato il meglio di te. Ti trovi, seduto, negli spogliatoi e ti viene riferito di aver impressionato positivamente i selezionatori e di essere stato ammesso nella squadra. Senti il tono della tua voce cambiare e ti senti esaltato per quel bellissimo risultato. Non potevi chiedere di meglio.

La premiazione in una competizione sportiva agonistica

Hai appena finito una gara sportiva. Sì, questa volta hai proprio vinto! Sei stanco, ma in questo momento non senti nulla se non una gioia enorme esplodere dentro di te. Sei in piedi, fermo davanti al pubblico presente e stai stringendo tra le mani il premio: lo tieni in alto perchè tutti lo possano vedere. Le tue mani sono sudate come, del resto, tutto il tuo corpo, ma non importa: oggi sei felice!

Il riconoscimento del tuo valore professionale

Sei seduto, nel tuo abituale posto di lavoro. Hai da poco portato a termine un progetto che ti ha impegnato per parecchio tempo, e il tuo superiore ne sta prendendo visione. Dopo un po' di attesa, ti viene comunicato di aver svolto un lavoro eccellente. Ti senti, a questo punto, sollevato, ma soprattutto, soddisfatto per tutto l'impegno che ci hai messo e per le rinunce che ha comportato quel lavoro. Senti un piacevole tepore diffondersi in tutto il corpo.

L'ottenimento di una promozione lavorativa

Sei stato chiamato dal tuo superiore e ti trovi in piedi, fermo, davanti a lui. Egli ti comunica che, viste le tue capacità, hai ottenuto quella promozione che speravi di ottenere da molto tempo. Sei felice perchè finalmente senti riconosciuti il tuo impegno e tutti i tuoi sforzi. Ti senti leggero come poche altre volte ti è capitato di sentirti.

L'inizio di una vita autonoma in una casa tua

Oggi per la prima volta dormirai nella tua nuova casa; l'hai cercata a lungo e finalmente hai trovato un appartamento che soddisfa tutte le tue esigenze e che ti permetterà di iniziare la tua nuova vita in autonomia. Dopo aver aperto la porta, ti fermi in piedi sull'uscio e getti uno sguardo sul tuo nuovo appartamento. Realizzi in quel momento di essere felice: non sai come sarà la tua nuova vita, ma provi una grande speranza per il futuro e senti nel tuo volto la tua espressione trasformarsi in sorriso.

Il tuo primo stipendio

Dopo un mese di lavoro, il tuo primo vero lavoro, hai ricevuto la prima busta paga. Ti siedi e la apri. Vedi l'ammontare dello stipendio, e non è tanto la cifra a colpirti, ma il fatto che quei soldi ti vengono dati in cambio del tuo impegno. Sai che dovrai dimostrarti responsabile e provi gioia perchè realizzi che sta cominciando una nuova vita indipendente per te. Nel tuo corpo i muscoli si rilassano.

Il riconoscimento delle tue abilità artistiche

Hai appena finito un'esibizione artistica*. Sei in piedi, fermo tra le persone presenti, che si avvicinano e si complimentano con te. Finalmente senti scioglierti il nodo che da alcune ore avevi in gola. Allora ti senti esaltato, perchè riconosci che quei complimenti non sono pure formalità, ma sono sinceri: quelle persone hanno riconosciuto il tuo talento artistico.

*potresti aver suonato in pubblico, messo in mostra delle tue produzioni artistiche, o letto in pubblico dei tuoi scritti, ecc.

La soddisfazione per aver espresso la tua arte

Sei in camera tua e ammiri ciò che hai fatto*, ti sembra che tutto sia perfetto e che le tue abilità artistiche ti abbiano permesso di realizzare qualcosa di veramente importante. Il ritmo del tuo respiro rallenta; ti senti in estasi nel contemplare quel prodotto che esprime al massimo la tua arte e già pensi a quale potrebbe essere la tua prossima creazione.

*potresti riascoltare una tua registrazione, riguardare un tuo dipinto o rileggere un tuo scritto, ecc.

L'aver reso felice una persona a te cara

Sei in piedi, vicino a una persona a te cara, per la quale hai fatto qualcosa che l'ha resa veramente felice*. Questa persona ti ringrazia e ti stringe le mani, sorridendoti e guardandoti negli occhi. I tuoi muscoli sono completamente rilassati. Ti senti felice per quel che hai fatto: ti rendi conto di averlo fatto volentieri perchè a quella persona vuoi davvero bene.

*potresti averla aiutata, averle dato conforto o fatto un regalo, ecc.

Un'esperienza di volontariato

Sei arrivato al termine di un'esperienza di volontariato durata alcuni mesi. Le persone che hai aiutato in questo periodo ti stanno salutando e tu sei in piedi, fermo in mezzo a loro. Le tue mani sono sudate per l'emozione. Ti senti felice e appagato per tutto il bene che ricevi e quello che hai imparato da quest'esperienza: insegnamenti importanti che ti porterai nel cuore per tutta la vita.

<u>Hedonic events</u>

Fare shopping con un caro amico

Tu e un tuo amico oggi avete deciso di andare a fare shopping. Non dovete acquistare nulla di particolare ma avete voglia di fare un giro fra i negozi per vedere se qualcosa attira la vostra attenzione. Ed ecco che passate davanti a un negozio che ti incuriosisce: guardando la vetrina, ti fermi e chiedi al tuo amico che ne pensa di alcuni degli articoli esposti. Provi allegria perchè stai passando un pomeriggio piacevole in compagnia del tuo amico e senti il corpo leggero.

Un indimenticabile pomeriggio di relax con gli amici

Oggi non hai impegni, avevi la casa a tua disposizione, così hai deciso di invitare alcuni amici per un pomeriggio in compagnia. Siete seduti sul divano, chiacchierate, bevendo qualcosa e ascoltando della buona musica. Ti rendi conto che pomeriggi così non capitano molto spesso; ti senti felice perchè ti stai davvero divertendo, e senti il tuo corpo leggero come una piuma.

Un pomeriggio di gioco con tuo nipote

Oggi sei andato a trovare tuo nipote, e hai deciso di passare il pomeriggio con lui a giocare. Avete appena finito una partita del suo gioco preferito, sei seduto davanti a lui, guardi la sua faccina felice e lo vedi ridere. Ti rendi conto che stai passando davvero un bel momento con lui, senti il cuore battere forte e provi amore per quel bambino che ti chiama "zio".

Un pranzo di festa in famiglia

E' una bella giornata: tu e la tua famiglia, oggi, dovete festeggiare un'importante ricorrenza. Siete seduti a tavola e, guardandoti intorno, vedi tutti i tuoi familiari sereni e radunati per quell'occasione come non succedeva da tempo. Per l'occasione tua madre ha preparato il tuo piatto preferito. Senti i muscoli del tuo volto distesi e provi una grande allegria diffondersi dentro di te.

L'inizio di una nuova storia d'amore

Hai conosciuto da qualche tempo una nuova persona, con la quale ti senti davvero in sintonia e sì, pensi di esserne innamorato. Avete appena deciso di cominciare ad uscire insieme e, dopo una passeggiata, avete raggiunto un posto da cui si gode di una vista magnifica. In piedi, davanti a quel panorama, stai tenendo la sua mano. Senti il tuo cuore accelerare il battito e provi grande gioia.

Una serata particolarmente romantica

Tu e il tuo partner siete finalmente in vacanza insieme e oggi avete deciso di passare una serata romantica. Avete deciso insieme che una cena a lume di candela, in riva al mare, sarebbe stato l'ideale. Seduti uno di fronte all'altro, in riva al mare, state cenando. Il cibo è delizioso, l'atmosfera è magica. Vi guardate negli occhi e tu senti i brividi attraversarti il corpo. A quel punto capisci di essere davvero innamorato e ti senti felice.

Un orgasmo indimenticabile

Sei sdraiato e dopo aver fatto a lungo l'amore, ti fermi e al culmine dell'eccitazione arrivi all'orgasmo. Un orgasmo così non l'avevi mai provato! Senti delle grandi vampate percorrerti tutto il corpo e resti immobile a goderti quelle piacevoli sensazioni. Ti senti in un forte stato di beatitutine che vorresti non finisse più.

Il primo rapporto sessuale con un nuovo partner

Conosci da poco questa persona e oggi, per la prima volta, avete fatto l'amore. Desideravate molto questo momento. E' stato molto bello scoprirsi, esplorare i propri corpi e iniziare a conoscersi anche sotto questo aspetto. Sei sdraiato, soddisfatto di come è andata e, dopo aver fatto l'amore, dai un bacio al tuo partner. Senti il battito del cuore che pian piano rallenta e ti senti in estasi.

Assistere ad un bellissimo film

Sei seduto tra il pubblico a vedere un film che finora ti ha appassionato fin dall'inizio. Guardi gli attori che mettono in scena la conclusione e ti senti realmente interessato a conoscere quale sarà l'epilogo della vicenda. Senti un nodo in gola per l'attesa, ma sei felice di essere lì a goderti quel momento.

Guardare in tv il tuo sport preferito

Finalmente questo momento è arrivato: l'hai atteso per tutta la giornata e ora sei seduto sul divano. Ti puoi godere il tuo sport preferito in TV. Ascolti la telecronaca e osservi le performance degli sportivi. Sei interessato a scoprire quel che succederà e senti il tuo corpo completamente rilassato.

Il tuo ultimo viaggio all'estero

Stai facendo un viaggio all'estero, in un paese che da molto desideravi visitare. In questo momento ti trovi in piedi, fermo, davanti a un paesaggio incredibile. Ammirandolo, senti il sole che ti scalda il volto e il vento che ti sfiora la pelle. Ti accorgi che un sorriso ti compare sul volto e provi serenità per il momento che stai vivendo.

La vacanza tanto sognata in un altro paese

La vacanza che da molto sognavi e che hai a lungo organizzato è iniziata! Appena sceso dall'aereo, ti fermi, in piedi e, guardandoti intorno, respiri per la prima volta quell'aria nuova. Ti piace! Il ritmo del tuo respiro rallenta e provi curiosità per quella nuova terra che non vedi l'ora di esplorare.

Neutral events

Andare al lavoro in automobile

Come quasi tutte le mattine, stai andando al lavoro in automobile. Hai l'autoradio accesa, sei seduto, ti senti tranquillo e non noti nulla di strano nel tuo corpo. Mentre guidi presti attenzione alla strada e pensi ai vari impegni della giornata.

Andare al lavoro in autobus

Oggi, come succede spesso, stai andando al lavoro in autobus. Hai trovato posto e ti sei seduto. Stai ascoltando alcune canzoni che hai caricato ieri sera sul tuo mp3. Sei sereno mentre guardi fuori dal finestrino e vedi la solita strada. Il tuo respiro è regolare.

Scaldare il pranzo

Come ti capita spesso di fare, stai scaldando il pranzo nel microonde. Oggi hai deciso di mangiare la pasta avanzata ieri a cena: seduto ad aspettare, guardi il cibo girare sul piatto mentre si scalda. Il tuo battito è regolare e non senti emozioni specifiche.

Aspettare che sia pronta la cena

Stasera non cucini tu. Hai aiutato ad apparecchiare il tavolo ed ora sei in piedi ad aspettare che sia pronta la cena. Senti il profumo del cibo, osservi chi finisce di cucinare e ci scambi due chiacchere parlando della tua giornata. La tua voce è normale e sei sereno.

Guardare il TG

Come ogni giorno stai guardando il telegionare. Sei seduto e ascolti e guardi il giornalista annunciare le notizie principali una dopo l'altra. Non è successo nulla di particolare e nessuna notizia desta particolarmente il tuo interesse, il tuo cuore batte regolarmente; non stai nè bene nè male.

Fare zapping alla TV

Sei seduto davanti alla TV e, cambiando continuamente canale, vedi pezzetti di programmi diversi. Nessuno cattura la tua attenzione, così preferisci passare da uno all'altro. I tuoi muscoli hanno una tensione normale e sei tranquillo.

Comprare il pane

Come ogni giorno ti sei fermato dal fornaio a comprare il pane. Ti saluta e tu gli chiedi di darti il pane che ti serve. Dopo aver ricevuto il sacchetto di pane sei in piedi fermo: il fornaio ti porge il resto e ti saluta. Il tuo volto è normale e non provi nessuna emozione particolare.

Fare colazione

Ti sei svegliato da poco e fai la tua solita colazione. Una tazza di the, fette biscotatte con la marmellata e un frutto. Ogni tanto controlli l'orologio per accertarti che non sia tardi mentre mangi quello che hai preparato. Senti il cibo scendere nello stomaco e ti senti quieto.

Controllare la mail

Come fai diverse volte in ogni tua giornata, stai controllando se sono arrivate nuove mail: seduto davanti al pc, dopo aver aperto il client di posta, aspetti che si aggiorni e guardi lo schermo. Non senti nulla di strano nel tuo corpo e ti senti calmo.

Sfogliare il giornale

Come tutte le mattine, seduto al bar dove passi a bere il caffè, stai sfogliando il giornale mentre attendi che sia pronto. Controlli se qualche notizia desta il tuo interesse. Giri le pagine e leggi i titoli principali ma nessuno cattura la tua attenzione. Il tuo respiro è regolare e sei tranquillo.

Aspettare l'autobus

Sei arrivato alla fermata dell'autobus, come ogni volta, guardi gli orari e vedi che arriverà fra 5 minuti. Sei in piedi, fermo e osservi la gente che come te aspetta. Ascolti alcuni stralci delle conversazioni delle persone che sono raccolte sotto la pensilina: il tuo cuore ha un battito normale e sei calmo.

Fare una telefonata per fissare un appuntamento

Sei seduto. Stai facendo una telefonata per fissare un appuntamento qualsiasi: senti che il telefono della persona che stai chiamando sta squillando e aspetti che ti risponda. Nel frattempo ti guardi intorno e pensi a quel che devi dire quando avrai risposta. Non senti nulla di strano nel tuo corpo e sei in uno stato di quiete.

HIGH MOTOR ACTIVATION

Eudaimonic events

Il superamento di un esame orale importante

Sono alcuni mesi che stai preparando questo esame, la materia ti interessa molto ma è anche piuttosto complessa. E' il tuo momento, il professore ha chiamato il tuo nome e ti trovi davanti a lui. Il tuo cuore accelera e lo senti battere forte, ma mentre esponi quello che sai, muovendoti ed esprimendoti con ampi gesti, ti senti orgoglioso per come stai superando quella prova: capisci che tutti i tuoi sforzi sono serviti per dare il tuo meglio oggi.

Un riconoscimento in ambito scolastico

Hai realizzato un lavoro eccellente! Il professore ti fa i complimenti e ti chiede di esporne brevemente il contenuto ai tuoi compagni. Perciò ti chiama alla cattedra. Stai esponendo il tuo lavoro davanti a tutti, sei in piedi e ti muovi continuamente mentre parli. Provi felicità perchè il tuo impegno è stato riconosciuto nello svolgere quel progetto a cui tenevi molto. Ti senti sorpreso e ti rendi conto che il tono della tua voce è un po' diverso dal solito.

La vittoria in una competizione sportiva

Stai partecipando ad una competizione sportiva per la quale ti sei allenato per mesi e che ti sta richiedendo un grande impegno fisico: questa vittoria significa molto per te. Il tempo sta per scadere e ce la metti tutta per vincere, ma vedi i tuoi avversari fare lo stesso. In ogni caso hai la fortissima speranza di vincere in questa competizione, e senti che ce la stai per fare. I tuoi muscoli sono tesi, ti stai muovendo per dare il meglio di te. Ti senti felice.

I festeggiamenti per un successo sportivo di squadra

Tu e la tua squadra avete vinto!! Speravate tanto in questo successo e alla fine ce l'avete fatta, tutti insieme! Dopo l'annuncio esultate e vi complimentate gli uni con gli altri. Tu salti e corri insieme ai tuoi compagni, e finalmente si scioglie la tensione muscolare che hai provato fino a questo momento. Ti senti orgoglioso della vittoria e sei felice di far parte di questa squadra.

La conclusione di uno stage particolarmente formativo

E' l'ultimo giorno di uno stage. In questi mesi hai provato a metterti in gioco in quella che un giorno potrebbe essere la tua professione. Stai camminando velocemente perchè hai ancora alcune cose da fare, e nel frattempo leggi il giudizio che il tuo tutor ha appena finito di scrivere sul tuo conto. E' davvero positivo, e leggendolo, ti rendi conto di aver dato il meglio di te. Ti senti soddisfatto di te stesso e ti accorgi che la tua espressione si trasforma in sorriso.

L'inizio di un nuovo lavoro

Ti stai recando al lavoro. Stai camminando velocemente per raggiungerlo in tempo e osservi la strada che d'ora in poi percorrerai tutti i giorni. Il tuo cuore batte forte; sei curioso di sapere quel che ti aspetta, come saranno i colleghi e quali saranno le tue mansioni. Sei felice per l'inizio di questa nuovo lavoro che hai cercato a lungo.

Il trovare casa per una convivenza

Tu e il tuo partner avete cercato a lungo una casa che rispondesse alle vostre esigenze e ai vostri desideri. Esplorando la nuova casa, finalmente sai di aver trovato quella che risponde al vostro ideale. Muovendoti freneticamente da una stanza all'altra, senti il tuo corpo leggero come una piuma e provi un'enorme serenità in quel posto che d'ora in poi sarà il vostro nido.

L'organizzazione di un evento culturale

Ti è stato chiesto di organizzare una serata culturale; dopo mesi di organizzazione e di impegno affinchè tutto andasse per il verso giusto, quella serata è arrivata. Camminando e parlando con i presenti, che ti chiedono informazioni e si complimentano con te, ti rendi conto di quanta gente è arrivata. I tuoi muscoli, dopo essere stati tesi a lungo per la paura che qualcosa andasse storto, finalmente sono rilassati. Ti senti felice e soddisfatto per l'ottimo lavoro che hai svolto.

Una tua esibizione artistica in pubblico

Ti muovi sul palco, davanti a moltissima gente, e stai mettendo in mostra le tue doti artistiche in una performance* che ti permette di dimostrare quello che sai fare. Senti i brividi percorrerti la schiena per l'emozione. Nonostante tutta quella gente, non hai paura, ma ti senti sereno perchè stai facendo quello che ti piace, e le reazioni del pubblico ti danno la conferma che lo sai fare bene.

*potresti cantare, suonare, dipingere, leggere dei tuoi scritti, ecc

L'espressione della tua passione artistica

Sei da solo, a casa tua, e ti stai godendo il tempo libero esprimendo la passione artistica che coltivi da tempo*. Sei in piedi e ti muovi e, mentre svolgi questa attività, i pensieri scompaiono e tutto intorno a te ha dei colori brillanti. Senti che il ritmo della respirazione si è abbassato e provi un profondo senso di beatitudine.

*potresti cantare, dipingere, suonare, scrivere, ecc

Aiutare un amico a svolgere un'attività

Sei venuto a sapere che un tuo amico ha bisogno di aiuto per svolgere un'attività*. Senza che lui te lo chiedesse, ti sei offerto. Stai spiegando al tuo amico perchè hai deciso di aiutarlo, mentre ti muovi svolgendo quell'attività. In quel momento ti accorgi di essere felice perchè sai che ne aveva davvero bisogno, ti senti interessato ad aiutarlo e senti il tuo corpo leggero.

*potresti aiutarlo in un trasloco, a studiare, a finire un lavoro per una scadenza, ecc.

Organizzare un evento di beneficenza

Hai organizzato un evento di beneficenza per devolvere fondi per una causa in cui credi molto. Mancano poche ore all'inizio dell'evento e ti stai muovendo per sistemare le ultime cose. Guardi la locandina dell'evento su cui c'è scritto il tuo nome e capisci di essere sereno: hai creato qualcosa di bello per aiutare gli altri. Provi una sensazione di calore che si diffonde in tutto il corpo.

<u>Hedonic events</u>

La vacanza al mare con gli amici

Tu e i tuoi amici avete organizzato una vacanza insieme al mare. L'hai attesa a lungo. Siete arrivati da poche ore e stai facendo il primo bagno. Col sole che ti scalda mentre nuoti, ti senti davvero spensierato: in questi giorni non dovrai pensare ad altro se non a rilassarti e divertirti. A quest'idea, senti di avere le farfalle allo stomaco e vuoi goderti questa vacanza.

Una bella festa con amici

Questa sera sei stato invitato ad una festa: ci sono tutti i tuoi migliori amici ed alcune persone nuove che sembrano interessanti. Balli e ti lasci andare, senti la musica e vedi tutti i tuoi amici ridere e scherzare. Ti stai davvero divertendo e vuoi goderti ogni istante della festa. A questo pensiero, il tuo cuore accelera il suo battito.

La festa per il compleanno di tua nonna

E' il compleanno di tua nonna e quest'anno, per festeggiarla, tu e i tuoi cari avete deciso di ritrovarvi a pranzo. Arrivi nel luogo che avete scelto per il pranzo, dove molti sono già arrivati. Quando li vedi vai ad abbracciarli e a salutarli uno per uno. Che bello vederli tutti riuniti in questa occasione. Provi una grande serenità e ti accorgi che, per la gioia, il tuo cuore sta battendo forte.

Il matrimonio di tuo fratello

Tuo fratello ha appena pronunciato il fatidico sì con la persona che gli starà accanto tutta la vita. Conclusa la cerimonia, vedi i due sposi arrivare mano nella mano. Colmo di felicità per questo passo importante per la vita di tuo fratello, stai lanciando il riso verso gli sposi e ti muovi verso di loro per fargli gli auguri. Ti senti molto allegro e provi tepore in tutto il corpo.

Il primo bacio con la persona che ami

E' da tempo che sei innamorato di questa persona, hai fatto di tutto per farti conoscere meglio e ti sembra che finalmente anche lei provi un interesse particolare nei tuoi confronti. Vi guardate negli occhi e le vostre labbra si toccano. Vi state abbracciando e baciando intensamente, le tue mani sono sudate e ti senti in estasi in questo momento che aspettavi da molto.

Una gita romantica in bicicletta

Tu e il tuo partner oggi avete deciso di fare una gita in bicicletta, da soli, immersi nella natura. Pedalando in posti meravigliosi, respirate mille profumi e, baciati dal sole, col vento che vi accarezza, vi sorridete. Nonostante la fatica, senti il tuo corpo molto leggero e ti senti davvero innamorato e sei felice di poter passare questo bel momento insieme.

Il bacio in discoteca

Questa sera hai deciso di andare in discoteca, avevi voglia di ballare. E' dall'inizio della serata che quella persona ti sta guardando con interesse e tu, dopo aver ricambiato i suoi sgardi, ti sei avvicinato. La musica è altissima, i vostri corpi sono vicini e vi muovete seguendo la musica. Al culmine dell'eccitazione, le vostre labbra si toccano e vi baciate. Le tue guance sono infuocate e tu sei felice per la tua conquista.

Un rapporto sessuale con una persona che conosci da poco

Conosci da poco questa persona, anche se ti è sembrata interessante fin dal primo momento. Oggi siete finiti a letto insieme. State per fare l'amore. Siete sdraiati e vi accarezzate. Tocchi il suo corpo nudo e senti un gran desiderio sessuale crescere dentro di te. Sei esaltato per quello che sta per succedere.

Il concerto di un gruppo musicale che adori

Adori questo gruppo musicale, pensi che siano dei grandi artisti e conosci a fondo la loro produzione. Oggi, finalmente puoi assistere ad una loro esibizione dal vivo. Sei in mezzo al pubblico e ascolti la tua canzone preferita. Dall'inizio del concerto aspettavi questa canzone, che più volte ti ha emozionato. Senti i brividi salirti lungo la schiena ascoltandola. Sei in piedi e salti e ti senti in estasi, come se intorno non ci fosse nessuno.

La partita che decreta la vittoria di campionato della tua squadra del cuore

Sei allo stadio a vedere questa che è una partita decisiva: se la tua squadra vince otterrà lo scudetto dopo un campionato che hai seguito settimana dopo settimana. Vedi l'attaccante segnare il gol decisivo; esulti e per la gioia abbracci chi ti sta vicino. Hai le vertigini e ti senti proprio esaltato: ora si deve festeggiare!

Il tuo primo viaggio, da solo, all'estero

E' la prima volta che fai un viaggio da solo ed hai deciso di andare all'estero: stai visitando questa nuova città e vedi moltissimi angoli affascinanti. Ti senti energico, stai camminando velocemente e provi la curiosità di esplorare ogni via per conoscere più a fondo quel posto nuovo e diverso da tutti i posti che conosci. Tutto ciò ti rende felice.

Fai nuove amicizie durante un viaggio all'estero

Da qualche giorno stai facendo un viaggio all'estero e oggi hai conosciuto due nuove persone. State camminando insieme e parlate per approfondire la conoscenza e sentire le storie che hanno da raccontarti. Questo ti rende molto felice. Senti calore nel tuo corpo e provi interesse per quello che ti stanno dicendo.

<u>**Neutral events**</u>

Andare al lavoro a piedi

Come tutti i giorni ti stai recando al lavoro a piedi. Osservi la strada che ormai conosci bene, incontri e saluti alcune persone che conosci e pensi a cosa dovrai fare oggi al lavoro. Mentre cammini, senti i piedi che poggiano a terra. Sei tranquillo.

Andare al lavoro in bici

Come ti capita spesso di fare, ti stai recando al lavoro in bici: mentre pedali, presti attenzione alla strada, osservi le automobili che ti passano vicine e saluti alcune persone. Le tue gambe hanno una tensione normale e sei sereno.

Cucinare il pranzo

Come fai abitualmente, stai cucinando il pranzo e hai deciso di seguire una ricetta particolare: dopo aver raccolto tutti gli ingredienti, guardi la ricetta e la realizzi passo passo. Sei in piedi e ti muovi per la cucina: ti sposti dal frigorifero, al lavandino, ai fornelli. Il tuo corpo è rilassato, sei quieto.

Cucinare la cena

Come fai abitualmente, stai cucinando la cena e hai deciso di preparare la solita pastasciutta col sugo. Sei in piedi e ti muovi, spostandoti tra la dispensa e i fornelli: l'acqua bolle, devi mettere il sale, buttare la pasta nella pentola e controllare che il sugo non si bruci. Il tuo battito è regolare, non stai nè bene nè male.

Mettere in ordine la cucina

Il pranzo è finito e stai sistemando la cucina. Sei in piedi e ti muovi tra il tavolo e il lavandino; l'acqua scorre e le tue mani sono bagnate perchè stai lavando le stoviglie. Respiri normalmente e non provi nessuna particolare emozione.

Fare le pulizie in camera

Come ti capita di fare una volta ogni tanto, stai facendo le pulizie in camera tua: sistemi il letto e i libri sparsi in giro per la camera. Il tuo corpo ha una temperatura normale. Ti stai muovendo per la camera e ti senti tranquillo, mentre pensi a dove mettere alcune delle cose che hai trovato sparse.

Fare la spesa

Come fai di routine, ti sei recato al supermercato per fare la spesa: guardi la lista e cerchi i prodotti fra i reparti. Il carrello è mezzo pieno e devi prendere ancora alcune cose, quindi cammini per andare a prenderle. Cerchi le offerte per spendere di meno. Non senti nulla di strano nel tuo corpo e non stai nè bene nè male.

Vestirsi per andare al lavoro

Come ogni mattina, dopo esserti lavato, stai decidendo come vestirti per andare al lavoro: guardi nell'armadio e scegli i vestiti da indossare. Il tuo volto ha un'espressione normale e, mentre sei in piedi e ti muovi per vestirti, sei in uno stato di calma.

Tagliare l'erba in giardino

Come ti capita spesso in questa stagione, stai tagliando l'erba in giardino: mentre cammini e spingi il tagliaerba, vedi l'erba che, al tuo passaggio, diventa corta. Senti odore di erba tagliata e presti attenzione a non lasciare parti non tagliate. I tuoi muscoli sono in un normale stato di tensione e sei sereno.

Salire le scale

Stai salendo le scale: senti il rumore dei tuoi passi e guardi quanti gradini mancano per arrivare a destinazione. Guardi i nomi scritti sui campanelli vicino alle porte che trovi e sei incuriosito dalle piante ornamentali che trovi sui pianerottoli. Il tuo battito è regolare e non provi nessuna emozione specifica.

Farsi una doccia

Ti stai facendo una doccia: senti il tuo corpo bagnato, il profumo del bagnoschiuma e il rumore dell'acqua che ti scorre sul corpo. Ti muovi per insaponarti e risciacquarti mentre ripensi alla tua giornata. Il tuo respiro è normale e sei sereno.

Andare a prelevare al bancomat

Sei uscito di casa e stai camminando per raggiungere lo sportello automatico per prelevare poichè hai bisogno di contanti. Guardi la strada e osservi le persone e le macchine che passano ma nulla cattura particolarmente la tua attenzione. Sei tranquillo e il tuo cuore batte al suo solito ritmo.

APPENDIX B: Lists of brain activations within each contrast

EUDAIMONIC VS NEUTRAL

Cluster 1	
Number of voxels: 1693	
Peak MNI coordinate: 28 -58 -44	
Peak intensity: 3.9503	
N° voxels	structure
1693	--TOTAL # VOXELS--
1652	Right Cerebellum
1452	Cerebellum Posterior Lobe
486	Cerebelum_Crus1_R (aal)
435	Cerebellar Tonsil
317	Cerebelum_Crus2_R (aal)
291	Uvula
279	Cerebelum_8_R (aal)
271	Declive
265	Tuber
233	Cerebellum Anterior Lobe
170	Pyramis
164	Cerebelum_6_R (aal)
144	Cerebelum_9_R (aal)
75	Culmen
65	Dentate
64	Nodule
53	Vermis_9 (aal)
33	Left Cerebellum
24	Vermis_8 (aal)
19	Cerebelum_9_L (aal)
14	Uvula of Vermis
8	Inferior Semi-Lunar Lobule
7	Fusiform_R (aal)
7	Cerebelum_7b_R (aal)
7	Fastigium
6	Fusiform Gyrus
6	Right Cerebrum
6	Temporal Lobe
4	brodmann area 37
4	Gray Matter
2	White Matter

Cluster 2	
Number of voxels: 469	
Peak MNI coordinate: 28 -14 -12	
Peak intensity: 3.3315	
N° voxels	structure
469	--TOTAL # VOXELS--
269	Right Cerebrum
133	Hippocampus_R (aal)
131	White Matter
128	Sub-lobar
118	Limbic Lobe
106	Parahippocampa Gyrus
77	Gray Matter
75	Extra-Nuclear
33	Cerebro-Spinal Fluid
33	Lateral Ventricle
25	ParaHippocampal_R (aal)
24	Right Brainstem
23	brodmann area 34
20	Temporal Lobe
19	Sub-Gyral
18	Amygdala
13	Lentiform Nucleus
13	Pons
12	Hippocampus
11	Midbrain
9	Uncus
6	Putamen
6	brodmann area 28
5	Lateral Globus Pallidus
4	brodmann area 35
3	Amygdala_R (aal)
2	Medial Globus Pallidus
1	Caudate Tail
1	Caudate
1	Optic Tract

Cluster 3	
Number of voxels: 2119	
Peak MNI coordinate: -42 16 -36	
Peak intensity: 4.7997	
N° voxels	structure

2119	--TOTAL # VOXELS--
1799	Left Cerebrum
1280	Temporal Lobe
791	White Matter
734	Gray Matter
623	Middle Temporal Gyrus
572	Temporal_Mid_L (aal)
491	Superior Temporal Gyrus
443	Frontal Lobe
388	Inferior Frontal Gyrus
316	Temporal_Pole_Sup_L (aal)
315	brodmann area 21
289	Frontal_Inf_Tri_L (aal)
288	Temporal_Pole_Mid_L (aal)
203	brodmann area 38
110	Inferior Temporal Gyrus
83	Temporal_Sup_L (aal)
73	Insula_L (aal)
73	Temporal_Inf_L (aal)
65	Frontal_Inf_Orb_L (aal)
52	brodmann area 22
50	Precentral Gyrus
49	Rolandic_Oper_L (aal)
48	brodmann area 47
46	Frontal_Inf_Oper_L (aal)
38	brodmann area 20
38	Frontal-Temporal Space
36	Sub-Gyral
34	Sub-lobar
28	brodmann area 45
26	Insula
24	Fusiform Gyrus
18	brodmann area 6
16	brodmann area 13
8	brodmann area 44
7	Extra-Nuclear

Cluster 4	
Number of voxels: 72	
Peak MNI coordinate: -18 -16 -34	
Peak intensity: 3.2591	
N° voxels	structure
72	--TOTAL # VOXELS--
8	ParaHippocampal_L (aal)
3	Pons
3	Left Brainstem
1	Parahippocampa Gyrus
1	Limbic Lobe
1	Left Cerebrum

Cluster 6	
Number of voxels: 158	
Peak MNI coordinate: 42 -86 -24	
Peak intensity: 2.9042	
N° voxels	structure
158	--TOTAL # VOXELS--
122	Right Cerebrum
122	Occipital Lobe
76	Inferior Occipital Gyrus
68	Gray Matter
66	brodmann area 18
48	White Matter
26	Middle Occipital Gyrus
25	Lingual_R (aal)
18	Occipital_Inf_R (aal)
16	Cerebellum Posterior Lobe
16	Declive
16	Fusiform Gyrus
16	Right Cerebellum
14	Fusiform_R (aal)
8	Cerebelum_Crus1_R (aal)
4	Lingual Gyrus
2	brodmann area 19

Cluster 7	
Number of voxels: 854	
Peak MNI coordinate: 14 -98 -24	
Peak intensity: 3.6439	
N° voxels	structure
854	--TOTAL # VOXELS--
346	Right Cerebellum
334	Cerebellum Posterior Lobe
304	Declive
213	Occipital Lobe

199	Left Cerebellum
194	Cerebellum Anterior Lobe
186	Vermis_6 (aal)
170	Lingual Gyrus
159	Culmen
152	Cerebelum_6_L (aal)
129	Cerebelum_6_R (aal)
107	Left Cerebrum
106	Right Cerebrum
95	Gray Matter
74	Lingual_L (aal)
72	White Matter
57	Lingual_R (aal)
53	Vermis_4_5 (aal)
37	Vermis_7 (aal)
35	Culmen of Vermis
32	brodmann area 18
32	Cerebelum_Crus1_R (aal)
30	Declive of Vermis
29	brodmann area 19
24	Fusiform_L (aal)
22	Fusiform Gyrus
15	brodmann area 17
10	Sub-Gyral
8	Cerebelum_4_5_R (aal)
8	Cerebelum_4_5_L (aal)
3	Middle Occipital Gyrus
2	Cuneus

Cluster 8	
Number of voxels: 60	
Peak MNI coordinate: -20 -30 -26	
Peak intensity: 2.5867	
N° voxels	structure
60	--TOTAL # VOXELS--
34	Cerebelum_4_5_L (aal)
29	Culmen
29	Left Cerebellum
29	Cerebellum Anterior Lobe
21	Pons
21	Left Brainstem
4	Cerebelum_3_L (aal)

2	ParaHippocampal_L (aal)
1	Fusiform_L (aal)

Cluster 8	
Number of voxels: 63	
Peak MNI coordinate: -48 26 -18	
Peak intensity: 2.9259	
N° voxels	structure
63	--TOTAL # VOXELS--
56	Left Cerebrum
23	Frontal_Inf_Orb_L (aal)
12	Temporal_Pole_Sup_L (aal)
10	Temporal Lobe
9	Frontal Lobe
8	Superior Temporal Gyrus
5	Gray Matter
4	Inferior Frontal Gyrus
3	brodmann area 47
2	brodmann area 38

Cluster 9	
Number of voxels: 1773	
Peak MNI coordinate: 30 -76 18	
Peak intensity: 2.9955	
N° voxels	structure
1773	--TOTAL # VOXELS--
1684	Occipital Lobe
1104	White Matter
968	Cuneus
873	Right Cerebrum
871	Left Cerebrum
567	Gray Matter
567	Middle Occipital Gyrus
381	Occipital_Mid_L (aal)
315	brodmann area 18
310	Calcarine_L (aal)
243	Occipital_Mid_R (aal)
181	Occipital_Sup_L (aal)
168	Occipital_Sup_R (aal)
135	Calcarine_R (aal)
130	Cuneus_R (aal)
120	brodmann area 19

117	Lingual Gyrus
116	brodmann area 17
82	Cuneus_L (aal)
65	Temporal Lobe
56	Sub-Gyral
28	Middle Temporal Gyrus
25	Inter-Hemispheric
11	Lingual_L (aal)
9	Lingual_R (aal)
7	Precuneus
3	brodmann area 31
3	Superior Occipital Gyrus
2	brodmann area 23

Cluster 10	
Number of voxels: 2652	
Peak MNI coordinate: 22 14 30	
Peak intensity: 3.7921	
N° voxels	structure
2652	--TOTAL # VOXELS--
2650	Right Cerebrum
2321	White Matter
1588	Sub-Gyral
1465	Frontal Lobe
464	Parietal Lobe
441	Sub-lobar
281	Gray Matter
277	Extra-Nuclear
193	Cingulate Gyrus
185	Limbic Lobe
143	Precuneus
120	Inferior Frontal Gyrus
92	Temporal Lobe
90	Putamen_R (aal)
76	Frontal_Inf_Oper_R (aal)
70	Frontal_Inf_Tri_R (aal)
64	Insula_R (aal)
56	Putamen
56	Lentiform Nucleus
46	Inferior Parietal Lobule
45	Insula
43	Middle Frontal Gyrus

38	Frontal_Mid_R (aal)
38	Thalamus
36	Occipital_Sup_R (aal)
30	brodmann area 31
30	brodmann area 13
25	brodmann area 45
24	Frontal_Sup_R (aal)
18	Pulvinar
17	brodmann area 47
16	Precuneus_R (aal)
16	Caudate
16	Hippocampus_R (aal)
15	brodmann area 8
14	Medial Frontal Gyrus
14	Caudate Body
14	Cingulum_Mid_R (aal)
13	Precentral Gyrus
12	Cuneus_R (aal)
12	brodmann area 40
12	Thalamus_R (aal)
11	Superior Temporal Gyrus
9	SupraMarginal_R (aal)
9	Middle Temporal Gyrus
8	Anterior Cingulate
7	brodmann area 44
7	Occipital_Mid_R (aal)
7	Lateral Ventricle
7	brodmann area 32
7	Cerebro-Spinal Fluid
6	Caudate_R (aal)
6	brodmann area 39
5	brodmann area 24
4	Postcentral Gyrus
4	Superior Frontal Gyrus
4	Claustrum
4	Corpus Callosum
4	Supramarginal Gyrus
3	Frontal-Temporal Space
3	brodmann area 2
3	brodmann area 9
3	Rolandic_Oper_R (aal)
2	brodmann area 46
2	Midbrain

2	Postcentral_R (aal)
2	Right Brainstem
2	Caudate Tail
1	brodmann area 6

Cluster 11	
Number of voxels: 196	
Peak MNI coordinate: -4 26 6	
Peak intensity: 3.3953	
N° voxels	structure
196	--TOTAL # VOXELS--
189	White Matter
162	Corpus Callosum
141	Sub-lobar
136	Extra-Nuclear
97	Right Cerebrum
79	Left Cerebrum
30	Sub-Gyral
30	Frontal Lobe
20	Inter-Hemispheric
16	Cingulum_Ant_R (aal)
12	Limbic Lobe
12	Anterior Cingulate
5	Lateral Ventricle
5	Cerebro-Spinal Fluid
1	brodmann area 24
1	Gray Matter

Cluster 12	
Number of voxels: 47	
Peak MNI coordinate: -22 32 10	
Peak intensity: 2.196	
N° voxels	structure
47	--TOTAL # VOXELS--
47	White Matter
47	Left Cerebrum
24	Frontal Lobe
24	Sub-Gyral
23	Extra-Nuclear
23	Sub-lobar
2	Putamen_L (aal)

NEUTRAL VS EUDAIMONIC

Cluster 1	
Number of voxels: 1418	
Peak MNI coordinate: 54 -54 38	
Peak intensity: 3.7304	
N° voxels	structure
1418	--TOTAL # VOXELS--
1128	Right Cerebrum
917	Parietal Lobe
563	Inferior Parietal Lobule
548	Gray Matter
455	White Matter
400	Parietal_Inf_R (aal)
396	brodmann area 40
376	Angular_R (aal)
306	Supramarginal Gyrus
219	SupraMarginal_R (aal)
211	Temporal Lobe
145	brodmann area 39
133	Middle Temporal Gyrus
82	Angular Gyrus
66	Occipital_Mid_R (aal)
38	Superior Temporal Gyrus
25	Temporal_Mid_R (aal)
5	brodmann area 7
3	Superior Parietal Lobule
2	Precuneus
2	brodmann area 19
2	Occipital_Sup_R (aal)
1	Postcentral Gyrus

HEDONIC VS NEUTRAL

Cluster 1	
Number of voxels: 7626	
Peak MNI coordinate: 40 -72 -56	
Peak intensity: 4.3357	
N° voxels	Structure
7626	--TOTAL # VOXELS--
2886	Cerebellum Posterior Lobe
2740	Right Cerebellum
1853	Occipital Lobe
1250	Right Cerebrum
1101	Left Cerebrum
1073	Gray Matter
1004	Cerebelum_Crus1_R (aal)
951	Declive
945	White Matter
810	Cerebelum_Crus2_R (aal)
623	Lingual Gyrus
572	brodmann area 18
556	Tuber
541	Cerebellar Tonsil
456	Left Cerebellum
443	Cuneus
405	Calcarine_L (aal)
336	Cerebelum_6_R (aal)
318	Sub-lobar
291	Inferior Occipital Gyrus
269	Pyramis
269	Middle Occipital Gyrus
256	Uvula
253	Inferior Semi-Lunar Lobule
240	Cerebellum Anterior Lobe
229	brodmann area 19
212	Pons
210	Cerebelum_Crus1_L (aal)
210	Left Brainstem
199	Extra-Nuclear
193	Occipital_Mid_L (aal)
189	Cuneus_L (aal)
187	Cerebelum_9_R (aal)
185	Fusiform Gyrus
184	Cerebelum_9_L (aal)
178	Cerebelum_8_R (aal)
173	Vermis_6 (aal)
167	Culmen
164	Lingual_R (aal)
158	Occipital_Inf_R (aal)
156	Occipital_Sup_L (aal)
141	Cerebelum_7b_R (aal)
138	Hippocampus_R (aal)
124	brodmann area 17
110	Right Brainstem
110	Inter-Hemispheric
101	Medulla
97	Cerebelum_Crus2_L (aal)
95	Limbic Lobe
92	Vermis_7 (aal)
89	Sub-Gyral
76	Temporal Lobe
70	Parahippocampa Gyrus
68	Lingual_L (aal)
53	Cerebelum_10_L (aal)
52	Cerebelum_6_L (aal)
51	Declive of Vermis
39	Cerebro-Spinal Fluid
38	Lateral Ventricle
32	Lentiform Nucleus
28	Precuneus_L (aal)
28	Cerebelum_10_R (aal)
28	Thalamus
27	Nodule
27	ParaHippocampal_R (aal)
26	brodmann area 34
25	Fusiform_R (aal)
25	Dentate
23	Fusiform_L (aal)
21	Occipital_Inf_L (aal)
21	Putamen
20	Culmen of Vermis
20	Occipital_Mid_R (aal)
20	Vermis_9 (aal)
19	Precuneus
18	Superior Occipital Gyrus
16	Parietal Lobe

12	Cerebelum_4_5_L (aal)
11	Pulvinar
10	brodmann area 28
10	Amygdala
10	Lateral Globus Pallidus
9	Uncus
9	Cerebelum_3_L (aal)
9	Caudate Tail
9	Caudate
8	Thalamus_R (aal)
7	Midbrain
7	brodmann area 35
7	Tuber of Vermis
6	brodmann area 7
6	Vermis_4_5 (aal)
5	ParaHippocampal_L (aal)
5	Insula
3	Optic Tract
3	brodmann area 37
2	Pallidum_R (aal)
1	Fourth Ventricle
1	Uvula of Vermis
1	brodmann area 22
1	Temporal_Inf_R (aal)
1	Amygdala_R (aal)
1	Medial Globus Pallidus
1	Hippocampus
1	Claustrum
1	Pyramis of Vermis

Cluster 2	
Number of voxels: 1689	
Peak MNI coordinate: 22 10 -42	
Peak intensity: 4.2595	
N° voxels	structure
1689	--TOTAL # VOXELS--
1069	Right Cerebrum
572	Frontal Lobe
512	Frontal_Inf_Orb_R (aal)
454	Gray Matter
414	Inferior Frontal Gyrus
393	Temporal_Pole_Mid_R (aal)
391	White Matter
332	Temporal Lobe
286	Superior Temporal Gyrus
205	brodmann area 38
192	Temporal_Pole_Sup_R (aal)
154	brodmann area 47
102	Middle Frontal Gyrus
83	Insula_R (aal)
83	Limbic Lobe
81	Fusiform_R (aal)
74	Uncus
52	brodmann area 11
45	Sub-Gyral
37	Frontal_Sup_Orb_R (aal)
27	Frontal_Mid_Orb_R (aal)
24	brodmann area 20
22	Temporal_Inf_R (aal)
17	Extra-Nuclear
17	Middle Temporal Gyrus
17	Sub-lobar
16	ParaHippocampal_R (aal)
14	brodmann area 13
6	Rectus_R (aal)
4	Inferior Temporal Gyrus
3	brodmann area 28
3	Olfactory_R (aal)
2	brodmann area 36
1	Subcallosal Gyrus

Cluster 3	
Number of voxels: 45	
Peak MNI coordinate: -32 2 -42	
Peak intensity: 2.6013	
N° voxels	structure
45	--TOTAL # VOXELS--
45	Left Cerebrum
33	White Matter
27	Temporal Lobe
27	Temporal_Inf_L (aal)
18	Limbic Lobe
18	Uncus
15	Inferior Temporal Gyrus

12	Gray Matter
11	brodmann area 20
11	Fusiform_L (aal)
9	Sub-Gyral
7	Temporal_Pole_Mid_L (aal)
3	Middle Temporal Gyrus
1	brodmann area 38

Cluster 4	
Number of voxels: 252	
Peak MNI coordinate: 30 -40 -32	
Peak intensity: 3.3991	
N° voxels	structure
252	--TOTAL # VOXELS--
214	Right Cerebellum
203	Cerebellum Anterior Lobe
148	Culmen
69	Cerebelum_6_R (aal)
43	Cerebelum_Crus1_R (aal)
29	Cerebelum_Crus2_R (aal)
23	Cerebelum_4_5_R (aal)
18	Pons
18	Right Brainstem
11	Cerebellum Posterior Lobe
10	Cerebellar Tonsil
1	Tuber

Cluster 5	
Number of voxels: 2750	
Peak MNI coordinate: -42 20 -34	
Peak intensity: 4.9699	
N° voxels	structure
2750	--TOTAL # VOXELS--
2012	Left Cerebrum
1030	Temporal Lobe
892	Frontal Lobe
844	Gray Matter
814	White Matter
743	Inferior Frontal Gyrus
497	Superior Temporal Gyrus
445	Temporal_Pole_Sup_L (aal)
424	Temporal_Mid_L (aal)
417	Frontal_Inf_Tri_L (aal)
405	Middle Temporal Gyrus
334	Temporal_Pole_Mid_L (aal)
303	Frontal_Inf_Orb_L (aal)
297	brodmann area 38
234	brodmann area 21
119	Frontal_Inf_Oper_L (aal)
115	brodmann area 47
103	Inferior Temporal Gyrus
72	Insula_L (aal)
72	brodmann area 45
59	Precentral Gyrus
58	brodmann area 44
50	Temporal_Inf_L (aal)
46	Middle Frontal Gyrus
44	Temporal_Sup_L (aal)
39	brodmann area 20
24	Fusiform Gyrus
20	Sub-Gyral
18	Frontal-Temporal Space
13	brodmann area 46
12	Limbic Lobe
11	Uncus
10	brodmann area 22
8	Precentral_L (aal)
6	Sub-lobar
5	Frontal_Mid_L (aal)
3	brodmann area 11
3	Extra-Nuclear
2	Insula
2	Frontal_Mid_Orb_L (aal)
2	Rolandic_Oper_L (aal)

Cluster 6	
Number of voxels: 7645	
Peak MNI coordinate: -8 52 52	
Peak intensity: 5.4439	
N° voxels	structure
7645	--TOTAL # VOXELS--
3911	Frontal Lobe
3233	Left Cerebrum
2374	Gray Matter

1550	Medial Frontal Gyrus
1489	White Matter
1427	Superior Frontal Gyrus
1367	Frontal_Sup_Medial_L (aal)
1185	Right Cerebrum
1143	brodmann area 10
619	Frontal_Mid_L (aal)
614	Frontal_Sup_Medial_R (aal)
591	Middle Frontal Gyrus
567	Frontal_Sup_L (aal)
500	Inter-Hemispheric
485	Limbic Lobe
457	brodmann area 9
438	Frontal_Med_Orb_L (aal)
417	Cingulum_Ant_L (aal)
411	Anterior Cingulate
334	brodmann area 8
275	Frontal_Med_Orb_R (aal)
262	brodmann area 32
212	Cingulum_Ant_R (aal)
180	Frontal_Sup_R (aal)
176	Sub-Gyral
120	Precentral_L (aal)
80	brodmann area 6
79	Inferior Frontal Gyrus
75	Cingulate Gyrus
71	brodmann area 11
53	Frontal_Sup_Orb_L (aal)
37	Frontal_Mid_R (aal)
24	Cingulum_Mid_L (aal)
19	Frontal_Sup_Orb_R (aal)
18	Precentral Gyrus
2	brodmann area 24
2	Frontal_Inf_Oper_L (aal)
2	Rectus_R (aal)

Cluster 7	
Number of voxels: 279	
Peak MNI coordinate: -30 -58 8	
Peak intensity: 3.2275	
N° voxels	structure
279	--TOTAL # VOXELS--

279	Left Cerebrum
232	White Matter
100	Temporal Lobe
86	Occipital Lobe
83	Sub-Gyral
58	Middle Temporal Gyrus
56	Calcarine_L (aal)
50	Sub-lobar
43	Limbic Lobe
41	Posterior Cingulate
26	Lingual Gyrus
26	Cerebro-Spinal Fluid
26	Lateral Ventricle
24	Extra-Nuclear
24	Lingual_L (aal)
21	Gray Matter
16	Occipital_Mid_L (aal)
14	brodmann area 30
14	Cuneus
10	Temporal_Mid_L (aal)
5	Precuneus_L (aal)
5	Middle Occipital Gyrus
3	brodmann area 31
2	Parahippocampa Gyrus
2	brodmann area 18
2	brodmann area 19

Cluster 8	
Number of voxels: 116	
Peak MNI coordinate: 0 -54 14	
Peak intensity: 2.6345	
N° voxels	structure
116	--TOTAL # VOXELS--
99	Posterior Cingulate
99	Limbic Lobe
66	Left Cerebrum
57	Gray Matter
51	Precuneus_L (aal)
32	Inter-Hemispheric
22	brodmann area 29
18	brodmann area 30
18	Right Cerebrum

17	brodmann area 23
15	Calcarine_L (aal)
6	Lingual_L (aal)
4	Vermis_4_5 (aal)
3	Precuneus_R (aal)
3	White Matter
3	Cerebelum_4_5_L (aal)
2	Calcarine_R (aal)

Cluster 9	
Number of voxels: 384	
Peak MNI coordinate: 8 -34 22	
Peak intensity: 3.4111	
N° voxels	structure
384	--TOTAL # VOXELS--
324	White Matter
272	Sub-lobar
254	Extra-Nuclear
228	Corpus Callosum
184	Right Cerebrum
141	Left Cerebrum
59	Inter-Hemispheric
40	Limbic Lobe
30	Posterior Cingulate
25	Gray Matter
24	Cingulum_Post_R (aal)
21	Thalamus_L (aal)
14	Thalamus
11	brodmann area 23
10	Cingulate Gyrus
9	Thalamus_R (aal)
9	Medial Dorsal Nucleus
4	Cerebro-Spinal Fluid
4	Lateral Ventricle
2	Sub-Gyral
2	Frontal Lobe

Cluster 10	
Number of voxels: 629	
Peak MNI coordinate: -2 -60 30	
Peak intensity: 3.2035	
N° voxels	structure
629	--TOTAL # VOXELS--
473	Left Cerebrum
398	Precuneus
354	Parietal Lobe
307	Precuneus_L (aal)
261	Gray Matter
206	White Matter
163	Limbic Lobe
145	brodmann area 31
139	Cingulate Gyrus
138	Right Cerebrum
108	brodmann area 7
88	Precuneus_R (aal)
71	Occipital Lobe
71	Cuneus_L (aal)
65	Cingulum_Post_L (aal)
33	Cingulum_Mid_L (aal)
32	Cuneus
28	Posterior Cingulate
24	Calcarine_L (aal)
18	Inter-Hemispheric
14	Sub-Gyral
14	Temporal Lobe
14	Cingulum_Post_R (aal)
6	brodmann area 23
6	Cingulum_Mid_R (aal)
4	Occipital_Sup_L (aal)
1	brodmann area 30
1	brodmann area 18

Cluster 11	
Number of voxels: 44	
Peak MNI coordinate: -38 6 68	
Peak intensity: 2.3305	
N° voxels	structure
44	--TOTAL # VOXELS--
2	Left Cerebrum
2	Middle Frontal Gyrus
2	Frontal Lobe

Cluster 12	
Number of voxels: 194	

Peak MNI coordinate: 6 16 76	
Peak intensity: 3.0539	
N° voxels	structure
194	--TOTAL # VOXELS--
12	Supp_Motor_Area_R (aal)
2	Supp_Motor_Area_L (aal)

NEUTRAL VS HEDONIC

Cluster 1	
Number of voxels: 6204	
Peak MNI coordinate: 40 -28 16	
Peak intensity: 3.9849	
N° voxels	structure
6204	--TOTAL # VOXELS--
4212	Right Cerebrum
3273	Parietal Lobe
2770	White Matter
2402	Gray Matter
1502	Frontal Lobe
1389	Left Cerebrum
1179	Inferior Parietal Lobule
1129	Postcentral Gyrus
708	brodmann area 40
640	Postcentral_R (aal)
569	Postcentral_L (aal)
552	Parietal_Inf_R (aal)
511	SupraMarginal_R (aal)
413	Temporal Lobe
413	Sub-lobar
408	Paracentral Lobule
396	Angular_R (aal)
387	Supramarginal Gyrus
376	brodmann area 6
370	Sub-Gyral
369	Parietal_Sup_R (aal)
369	Insula
366	Precentral Gyrus
329	Paracentral_Lobule_L (aal)
300	Temporal_Sup_R (aal)
294	Precuneus_R (aal)
284	Medial Frontal Gyrus
259	brodmann area 7
242	brodmann area 5
225	Precuneus
216	Precentral_R (aal)
205	Precuneus_L (aal)
196	brodmann area 3
196	Superior Temporal Gyrus
196	Insula_R (aal)
168	Frontal_Sup_R (aal)
164	brodmann area 13
157	Rolandic_Oper_R (aal)
154	Superior Parietal Lobule
153	Middle Frontal Gyrus
136	Transverse Temporal Gyrus
129	Supp_Motor_Area_R (aal)
129	Paracentral_Lobule_R (aal)
128	Parietal_Inf_L (aal)
105	Heschl_R (aal)
99	brodmann area 4
98	Superior Frontal Gyrus
93	Parietal_Sup_L (aal)
93	brodmann area 41
88	brodmann area 2
65	Middle Temporal Gyrus
46	Temporal_Mid_R (aal)
40	Precentral_L (aal)
40	brodmann area 42
33	Supp_Motor_Area_L (aal)
32	Frontal_Sup_L (aal)
31	Angular Gyrus
31	Claustrum
29	brodmann area 1
23	brodmann area 22
22	Inter-Hemispheric
19	Extra-Nuclear
19	Cingulum_Mid_L (aal)
18	Cingulum_Mid_R (aal)
17	brodmann area 43
15	brodmann area 39
13	brodmann area 21
2	brodmann area 31

Cluster 2	

Number of voxels: 137	
Peak MNI coordinate: -12 -70 52	
Peak intensity: 2.8671	
N° voxels	structure
137	--TOTAL # VOXELS--
131	Left Cerebrum
131	Parietal Lobe
89	Precuneus_L (aal)
81	brodmann area 7
81	Gray Matter
71	Precuneus
60	Superior Parietal Lobule
48	Parietal_Sup_L (aal)
36	White Matter

Cluster 3	
Number of voxels: 197	
Peak MNI coordinate: -30 -18 60	
Peak intensity: 3.76	
N° voxels	structure
197	--TOTAL # VOXELS--
197	Left Cerebrum
196	Frontal Lobe
182	Precentral Gyrus
173	Precentral_L (aal)
132	White Matter
60	Gray Matter
44	brodmann area 6
14	brodmann area 4
7	Middle Frontal Gyrus
6	Postcentral_L (aal)
6	Sub-Gyral
2	brodmann area 3
2	Postcentral Gyrus
1	Parietal Lobe

EUDAIMONIC VS HEDONIC

Cluster 1	
Number of voxels: 3816	
Peak MNI coordinate: 16 -26 64	
Peak intensity: 3.7153	
N° voxels	structure
3816	--TOTAL # VOXELS--
2544	Frontal Lobe
1975	Right Cerebrum
1922	White Matter
1605	Left Cerebrum
1368	Gray Matter
1036	Parietal Lobe
771	Precentral Gyrus
722	Postcentral Gyrus
681	Medial Frontal Gyrus
610	brodmann area 6
494	Precentral_R (aal)
455	Postcentral_L (aal)
453	Postcentral_R (aal)
422	Sub-Gyral
410	Paracentral_Lobule_L (aal)
330	Paracentral Lobule
309	Supp_Motor_Area_R (aal)
304	Superior Frontal Gyrus
300	Supp_Motor_Area_L (aal)
252	brodmann area 3
229	brodmann area 4
209	Parietal_Sup_R (aal)
192	Paracentral_Lobule_R (aal)
189	Precentral_L (aal)
189	Frontal_Sup_R (aal)
177	Middle Frontal Gyrus
102	Precuneus_L (aal)
100	brodmann area 7
96	Superior Parietal Lobule
71	brodmann area 40
60	Frontal_Sup_L (aal)
58	brodmann area 5
56	Inter-Hemispheric
49	Inferior Parietal Lobule
42	Parietal_Inf_R (aal)
30	Precuneus
27	brodmann area 2
24	Precuneus_R (aal)
21	brodmann area 1
15	Parietal_Inf_L (aal)
7	Parietal_Sup_L (aal)

1	Cingulum_Mid_L (aal)

HEDONIC VS EUDAIMONIC

Cluster 1	
Number of voxels: 1303	
Peak MNI coordinate: -4 72 -8	
Peak intensity: 3.3586	
N° voxels	structure
1303	--TOTAL # VOXELS--
835	Frontal Lobe
579	Right Cerebrum
560	Medial Frontal Gyrus
475	Gray Matter
378	Left Cerebrum
346	White Matter
270	brodmann area 10
254	Frontal_Med_Orb_L (aal)
251	Frontal_Med_Orb_R (aal)
234	Superior Frontal Gyrus
183	Inter-Hemispheric
154	Frontal_Sup_Medial_R (aal)
154	Cingulum_Ant_R (aal)
148	Frontal_Sup_Medial_L (aal)
103	Anterior Cingulate
103	Limbic Lobe
82	Cingulum_Ant_L (aal)
80	brodmann area 11
63	brodmann area 32
55	brodmann area 9
39	Frontal_Sup_Orb_L (aal)
34	Frontal_Sup_Orb_R (aal)
15	Sub-Gyral
9	Middle Frontal Gyrus
6	Rectus_L (aal)
6	Frontal_Mid_Orb_L (aal)
3	brodmann area 24
2	Frontal_Mid_Orb_R (aal)
1	Frontal_Sup_R (aal)
1	Frontal_Sup_L (aal)

Cluster 2	
Number of voxels: 1898	
Peak MNI coordinate: 12 50 54	
Peak intensity: 3.7543	
N° voxels	structure
1898	--TOTAL # VOXELS--
530	Frontal Lobe
440	Right Cerebrum
350	Gray Matter
316	Middle Frontal Gyrus
252	Frontal_Mid_R (aal)
196	Superior Frontal Gyrus
184	brodmann area 8
91	Frontal_Sup_R (aal)
90	Left Cerebrum
89	White Matter
77	brodmann area 9
69	brodmann area 10
44	Frontal_Sup_Medial_R (aal)
44	Frontal_Mid_L (aal)
20	brodmann area 46
15	Frontal_Sup_Medial_L (aal)
15	Frontal_Sup_L (aal)
4	Sub-Gyral

Cluster 3	
Number of voxels: 182	
Peak MNI coordinate: -8 68 28	
Peak intensity: 3.4687	
N° voxels	structure
182	--TOTAL # VOXELS--
48	Frontal_Sup_Medial_L (aal)
23	Left Cerebrum
23	Frontal Lobe
13	brodmann area 10
13	Gray Matter
11	Superior Frontal Gyrus
10	Frontal_Sup_L (aal)
6	Middle Frontal Gyrus
2	Inter-Hemispheric
1	Medial Frontal Gyrus

Cluster 4	
Number of voxels: 87	

Peak MNI coordinate: - 12 34 30	
Peak intensity: 3.2966	
N° voxels	structure
87	--TOTAL # VOXELS--
87	Left Cerebrum
58	Medial Frontal Gyrus
54	Frontal Lobe
49	Frontal_Sup_Medial_L (aal)
38	White Matter
36	Gray Matter
33	Limbic Lobe
23	Anterior Cingulate
22	brodmann area 9
16	Frontal_Sup_L (aal)
15	Cingulum_Ant_L (aal)
14	brodmann area 32
6	Cingulate Gyrus