The sensitivity of Pavlovian to Instrumental Transfer (PIT) paradigm to measure wanting for pleasant olfactory stimuli

CHILLA, Chiara

Abstract

In sensory and consumer science, it has long been posited that liking measurement was the best method to understand preference and food choice behaviour (De Graaf et al., 2005; Kamen, 1962; Peryam & Pilgrim, 1957; Pilgrim, 1961; Pilgrim & Kramen, 1963; Schutz, 1957). Indeed, consumers laboratory experiments showed that products with high liking score are more often chosen compared to products with low liking score (De Graaf et al., 2005). However, newly pleasant products launched on the market, are not always the mostly bought by the consumers and do not have the success expected by business department. Consequently, a question is raised: Is the most pleasant product, the one that consumers really want? In addition, is it possible to measure independently the liking level from the motivation to obtain a specific product? Currently, the approaches used in industry to evaluate liking (and more globally the other emotions elicited by products) have their origin in clinical and academic psychology research (Cardello & Jaeger, 2016). A well-established theoretical framework to study liking and motivation is the Incentive [...]

Reference

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THE SENSITIVITY OF PAVLOVIAN TO INSTRUMENTAL TRANSFER (PIT) PARADIGM TO MEASURE “WANTING” FOR PLEASANT OLFATORY STIMULI

THESE

Présentée à la Faculté de psychologie et des sciences de l’éducation de l’Université de Genève pour obtenir le grade de Docteur en Psychologie

par

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ABSTRACT

In sensory and consumer science, it has long been posited that liking measurement was the best method to understand preference and food choice behaviour (De Graaf et al., 2005; Kamen, 1962; Peryam & Pilgrim, 1957; Pilgrim, 1961; Pilgrim & Kramen, 1963; Schutz, 1957). Indeed, consumers laboratory experiments showed that products with high liking score are more often chosen compared to products with low liking score (De Graaf et al., 2005). However, newly pleasant products launched on the market, are not always the mostly bought by the consumers and do not have the success expected by business department. Consequently, a question is raised: Is the most pleasant product, the one that consumers really want? In addition, is it possible to measure independently the liking level from the motivation to obtain a specific product?

Currently, the approaches used in industry to evaluate liking (and more globally the other emotions elicited by products) have their origin in clinical and academic psychology research (Cardello & Jaeger, 2016). A well-established theoretical framework to study liking and motivation is the Incentive Salience Theory (IST). The IST posits that the pursuit of a positive outcome (reward) depends on three distinct components: the motivation to obtain it (wanting), the pleasure felt during the consumption of it (liking), and the automatic associations and/or cognitive representations of the reward (learning). Animal studies have allowed measuring independently these components. Recently, based on animal methodology, a multitude of methods have been developed to measure the components of reward system in human. However, investigation of these components in human is more complex, mainly because more facets of the same components are presented in human and because human are able to fake a lot of behaviours. A promising method to be used in industrial setting to investigate consumer motivation, is the Pavlovian to Instrumental Transfer (PIT) paradigm. In fundamental research, this procedure provides a pure measure of the effort engaged to obtain a reward (“wanting”) independently of liking level felt during consumption of it and without asking explicitly cognitive desires motivating participant to obtain a reward. This thesis sought to (i) examine the sensitivity of the PIT procedure to measure “wanting” when two olfactory pleasant stimuli are simultaneously used, (ii) test the PIT procedure according to the physiological state of the participant and (iii) experimentally dissociate “wanting” from liking according to the
needs of the participant. Finally, this thesis tried to bring evidence to conclude whether PIT could be used as a practical tool in industrial setting.
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1. INTRODUCTION AND OVERVIEW
Introduction
In sensory and consumer science, preference and choice behaviour are mostly investigated by means of liking measurement showing that products with high liking score are more often chosen compared to products with low liking score behaviour (De Graaf et al., 2005; Kamen, 1962; Peryam & Pilgrim, 1957; Pilgrim, 1961; Pilgrim & Kramen, 1963; Schutz, 1957). However, newly pleasant products launched on the market, are not always the mostly bought by the consumers and do not have the success expected by business department. Understanding the motives behind the choice of a product is of major importance and cannot be reduce on a simple assessment of pleasure reinforced by it.

Methods used in industrial settings come both from applied and fundamental research.
In psychology and neuroscience field, the Incentive Salience Theory (IST) is used to explain how our daily actions are influenced by pleasant and unpleasant stimulations. It posits that the pursuit of an outcome is not directly proportional to the liking delivered during its consumption, but it is influenced by the motivation that an organism is ready to invest to obtain this outcome. Pioneers of the theory, Berridge and Robinson (1993), argued that the pursuit of a positive outcome (reward) is influenced by the pleasure felt during the consumption of it (liking), the motivation to obtain this reward (wanting), and automatic associations or cognitive representations of the reward (learning) (Robinson & Berridge, 1993, 2003; Berridge & Kringelbach, 2008). Based on rodent studies (Wyvell & Berridge, 2000), the IST showed that it is possible to measure the liking component independently from the wanting component. According to Berridge et al. (2009 a, b), the “liking” component can be measured by collecting the orofacial expressions, and the “wanting” component by collecting the effort mobilized to obtain an outcome. Typically, the three components of the reward mechanism are positively correlated (you “want” what you “like” and you “learned” from previous experiences) but can also be dissociated (such as in an addict's brain) with the consequence that an individual feels excessive motivation for a reward, but a decrease in its enjoyment when it is obtained (Robinson et al., 2016; Robinson & Berridge, 1993). Measuring the dissociation of these components in humans is still under investigation and several issues exist because it is not possible to directly extend the animal models to human research. In fact, humans are able to fake facial expressions and inhibit consummatory impulses (Tibboel et al., 2011).
Recently, based on animal methodology, a multitude of methods have been developed to measure the components of reward system on human. However, the main issue in human research is the
operationalization of the “wanting” and “liking” components as defined by the IST. A paradigm adapted from rodent research to study “wanting” in human is the Pavlovian-to-Instrumental Transfer (PIT) test. It is a procedure testing “wanting” in the absence of the liking component. It can potentially be applied in industrial settings to measure consumer motivation where two products are compared. However, it has never been used to investigate “wanting” in complex experimental settings where two olfactory stimuli are used. The aim of this thesis is threefold: (a) testing the PIT procedure in fragrance and flavour context when two olfactory pleasant stimuli are simultaneously used, (b) testing the PIT procedure according to the physiological state of the participant, and (c) experimentally dissociating “wanting” from liking according to the needs of the participant.

An overview of the goal and the structure of this thesis

This thesis is structured as follows: In the theoretical part (chapter 2), we first define the concept of reward and of wanting, as used in this thesis, and present the Incentive Salience Theory (IST). We then review literature on wanting measurements in human. Next, we present the Pavlovian-to-Instrumental Transfer (PIT) paradigms that have been used to investigate “wanting” in human in the last decade. Finally, we will present the thesis objectives: investigating whether the PIT procedure could be an empiric measure allowing to measure the motivation to obtain an olfactory reward in the presence of (i) a second less rewarded olfactory stimulus, (ii) a second highly rewarded olfactory stimulus (iii) a second more relevant rewarded stimulus, according to the goals of the subject in two specific moments: in a dirty environment and in a hunger state manipulated through a satiation devaluation. The more practical goal of this thesis is to test whether PIT paradigm can be a more efficient method compared to liking-rating test used to measure the satisfaction of consumers in fragrance and flavour industrial setting.

In the experimental part (chapter 3), we present the 4 experiments conducted to fulfil these objectives. We decided to start our investigation by developing a PIT test in which multiple olfactory stimuli were used. In fact, odours are ideal stimuli for influencing the “wanting” component of the reward process, because they are primary rewards having an innate value, a biological significance (Gottfried, 2011) and can be easily manipulated. In the first study, we questioned whether the PIT could measure the “wanting” when two olfactory stimuli having different rewarded proprieties were presented (section 3.3). In the second study, we questioned
whether the PIT could measure the “wanting” when two olfactory stimuli having similar rewarding proprieties were presented (3.4). Based on the results of these experiments, we further investigated the “wanting” component of the reward process by empirically testing factors that increased the salience of a reward, as suggested by IST. In experiment 3, we induced a physical disgust feeling in healthy individuals and tested their motivational response to obtain cosmetic related and food related olfactory stimuli with a similar liking level (3.5).

In experiment 4, we manipulated the physiological state of hunger via a satiation devaluation in healthy subjects, and tested the effect on learning processes of the PIT and specifically on subject’s unconscious desire to obtain food and cosmetic olfactory rewards with a similar liking level (3.6).

To conclude, in chapter 4, we combined the findings of empirical studies with the framework presented in the theoretical section. We discussed theoretical and practical implications of these findings. Finally, the limitations of our research and potential future perspective were discussed.
2. THEORETICAL PART
The theoretical part of this thesis is divided into four sections. In section 2.1, the concept of reward and the reward theory used in this thesis will be presented. An overview of the methods used to measure “wanting” will be presented in section 2.2. Among, the different methods proposed in the literature, we will focus our attention on the Pavlovian-to-Instrumental Transfer (PIT) paradigm (section 2.3). In recent years, it has been adapted from animal studies and used in human to independently measure “wanting” from liking component. The PIT paradigm will be deeply presented and main experiments using this procedure in humans will be summarized. The section 2.4 will be focused on the rewarded stimuli (the odours) especially created and used in PIT experiments to measure “wanting”. In addition, the four principal dimensions of olfactory perception and the functions of olfaction will be highlighted.

2.1 Reward definition and Incentive Salience Theory

The response to a reward varies from one individual to another, but generally each person wants to experience positive stimulation, such as reward, and avoid negative stimulation, such as punishment. In our daily life, actions are often influenced by reward-related cues which can both prompt us towards or stop us from initiating a specific action. For instance, smelling the odour of our favourite food can make us hungry and it can lead us to seek out for it. A reward can be defined as « any stimulus, object, event, activity, or situation that has the potential to make us approach and consume it» (Schultz, 2006, p. 5). Attractive and motivational properties of a stimulus are not entirely defined by his physical properties but by the behavioural reactions that it induces (Schultz, 2006). This is the reason why, Berridge and Kringelbach (2008), argued that « reward lies in active processes of the brain and mind that reacts to a stimulus rather than the stimulus itself » (Berridge & Kringelbach, p. 2). From an evolutionary perspective, the functions of reward are to make us eat, drink and mate in order to ensure the survival of ourselves and our species. Rewards are rewarding because they restore physiological homoeostasis and more largely provoke pleasure or cessation of pain. A well-established framework of reward process is the Incentive Salience Theory (IST) which proposes three distinct psychological components of the reward system: (a) wanting, consisting of a motivational state triggered by the perception of a reward; (b) liking, consisting of pleasure experienced during the consumption of the reward; and (c) learning, consisting of automatic associations, cognitive representations and predictions about future reward based on past experiences. These psychological components correspond to distinguishable neurobiological mechanisms (Berridge & Robinson, 2003; Dickinson & Balleine, 2002; Everitt & Robbins, 2005; Kelley et al., 2005; Kringelbach, 2005; Kringelbach & Berridge, 2008; Leknes & Tracey, 2008; Schultz, 2006). Beside the definition of wanting, liking, and learning as mental components, three other definitions can be found in the
literature. In the following section, the four possible definitions of reward components will be presented.

2.1.1 Mental definition of the reward's components

Reward components are most commonly defined as mental processes. Over the years, the definitions of liking, wanting, and learning have considerably evolved to become the definitions presented above (e.g., Robinson & Berridge, 1993, 2000, 2003; Berridge et al., 1996, 2009 a, b; Berridge & Robinson, 1995, 1998, 2003; Wyvell & Berridge, 2000, Berridge & Aldridge, 2008; Winkielman & Berridge, 2003, Berridge & Kringelbach, 2008, Berridge & O’Doherty, 2014, Berridge, 2004, 2007). Initially, the terms wanting and liking have been used in accordance with the common definitions of these mental processes. In particular, wanting was defined as a strong feeling of craving (Robinson & Berridge, 1993, p. 249) and liking as the common term of pleasure. In later papers, the two psychological processes were defined in terms of pre-conscious mechanisms and the result of these processes was thought to be conscious (Berridge & Robinson, 1995, Berridge, 1996). In 2010, Berridge proposed another differentiation: “wanting” and “liking” with and without quotation marks. “Wanting” and “liking” with quotation marks referred to their meaning in the IST context. Wanting and liking without quotation marks referred to the common sense of the terms motivation and pleasure. Thus, “wanting” with quotation marks is the motivational attractiveness of a stimulus (incentive salience) that does not always require consciousness and leads “animals and humans to approach and work to obtain the reward” (Anselme & Robinson, 2016, p.124). Wanting without quotation marks is a subjective conscious desire linked to past hedonic experiences. It is only in reference to this component that we can speak about imagination and declarative goal: based on past pleasurable experiences, we want a stimulus and we may imagine it in advance of getting it.

The same distinction was proposed for the liking component. “Liking” (with quotation marks) refers to a hedonic reaction that is not accompanied by conscious pleasure. Liking (without quotation marks) can be defined as the subjective hedonic reactions referring most directly to a conscious experience or subjective feeling of pleasure. It is a synonym of the common term of pleasure and refers to the subjective feeling of niceness. From this point of view, pleasure is never merely a sensation but always needs the brain to make it liked. Humans have a multitude of sensory systems that provide data from the surrounding environment. However, if there are not specific brain systems that paint an additional hedonic gloss (Berridge & Kringelbach, 2008) on the sensation, the latter is not by default a pleasurable stimulation.

In further research, wanting and liking were later defined as explicit or implicit psychological processes (Kringelbach & Berridge, 2010) mostly differing in their access to consciousness. Explicit
processes are consciously experienced and include the psychological concepts of *explicit pleasure, happiness, desire or expectation*. Implicit processes are potentially unconscious: they can operate at the level not always directly accessible to consciousness (*incentive salience, “liking” reactions*). The differentiation between implicit and explicit processes is much more relevant for wanting than for liking. In fact, explicit and implicit liking refer both to hedonic impact of reward consumption. This is not the case for wanting. Explicit wanting refers to subjective feeling of being attracted toward a desired object. As presented before, this component is dependent from liking (past hedonic experiences). Implicit wanting refers to the definition of incentive salience: an irrational motivational process that makes stimuli attractive (Berridge & Kringelbach, 2008). According to this classification, explicit and implicit wanting relies on two different systems: the first one on a goal-directed system, and the second one on a Pavlovian system (Berridge & Aldridge, 2008).

Learning includes associations, representations and predictions about future rewards. Learning processes are developed based on past experiences. The predictions can be associative, implicit, explicit and cognitive according to the way they are acquired. For instance, associative conditioned predictions are constituted by Pavlovian and instrumental associations. Through repeated Pavlovian conditionings an organism automatically learns (without the subject's own active participation) that a stimulus acquires the capacity to evoke a response that was originally evoked by another stimulus. Pavlovian mechanism was discovered by Russian physiologist I. Pavlov (1849-1936). In the early twentieth century, while studying the role of saliva in dogs’ digestive processes, he discovered a phenomenon he labelled “psychic reflexes”. Pavlov paired a meat powder with various stimuli such as the sound of a bell. After the meat powder and bell (auditory stimulus) were presented together several times, the bell was used alone. After multiple trials, he discovered that the dog salivated to the sound of a bell (auditory stimulus) even when food was not presented. In this experiment, the dog was only watching the situation and no action was required from him: he saw that the bell predicted, independently from his action, the food delivery and learned passively the association. Concerning instrumental learning, B. F. Skinner (1904-1990) described it as a learning process in which reinforcement or punishment are used to either increase or decrease the probability that a behaviour will occur again in the future. E. L. Thorndike (1874-1949) was one of the first to observe the impact of reinforcement in experiment showing that a cat could learned a specific action delivering a food reward. Specifically, a cat (placed in a cage during an experiment) learned that pressing a lever gave the opportunity to access to pleasant food. In this case, the cat liked the food and learned that his action allowed him to acquire food rewards. The more rewards cat got, the more it would press the lever again. In instrumental conditioning, reward becomes a positive reinforcer (something that makes an individual come back for more). Pavlovian and instrumental learning occur frequently
together. According to the value that an organism gives to an outcome, the behavioural reaction can be an approach response or an avoidance response.

2.1.2 Effect definition of the reward's components

The effect definition emerged from the study of drug effects on non-human animals (Berridge et al., 2009). Berridge and co-workers gave only a definition of the effect of “wanting” on a conditioned stimulus (CS). The “liking” component is not concerned with the effect definition.

“Wanting” can be defined as “the acquisition of a visceral and unconscious desire for a reward” (Robinson et al., 2016, p. 107). All cues associated to this reward can acquired the same motivational value given to that reward and consequently becoming “wanted” too.

According to this definition, the reward-associated cues are imbued with incentive salience and acquired three fundamental characteristics: become a motivational magnet, become a reinforcer in the absence of the reward and trigger sudden surges in effort to obtain a reward. These cues are not innate but acquire their motivational value through associative learning (Lovibond et al., 2015).

For instance, the simple logo of a well know food brand may prompt the need to eat meat. In this case, the cue become a “motivational magnet”, because like a magnet it “draws” attention and it becomes difficult to be ignored. This phenomenon has been tested in laboratory where animal is first trained to associate a cue with a reward and second in a novel task, the experimenter presents the cue alone (that is become a “motivational magnet”) and observe if the animal works to obtain it. In this second task, the animal is no longer receiving a reward (unconditioned stimulus, or UCS) and it is the cue (previously associated with the UCS) that generate the sustained attention of the animal (conditioned stimulus, or CS). CS becomes rewarding in itself. In this case, the CS become the conditioned reinforcer having the ability to foster new behaviours (Robinson et al., 2016). Moreover, research showed that a rewarding CS can trigger sudden large increase in effort to obtain the reward. In laboratory, this third characteristic acquired by a reward-associated cue is studied by means of the Pavlovian to Instrumental Transfer (PIT) test. In this paradigm the “wanting” is operationalized as the number of squeezes (effort) performed on a hand grip to obtain a previous reward. The increase of these peaks is seen as “surges in effort” to obtain a previously reward when a CS is presented alone.

2.1.3 Utility definition of the reward's components

Berridge and Aldridge (2008) defined wanting and liking in term of the utility of specific goals and how they drive behaviour. The authors argued the existence of 4 types of utility. Predicted utility (expectation of hedonic impact of a future reward), decision utility (essence of decision at the moment it is made), experienced utility (hedonic experience produced by the reward once it is obtained) and
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remembered utility (memory of how pleasant the reward was after consumption). Experienced utility can be understood as liking, decision utility as wanting. Authors do not differentiate between conscious and unconscious processes. If there is a dissociation between predicted utility, decision utility and experienced utility, the individual’s decision is not optimal and a “miswanting” occurs. The authors called “irrational miswanting”, the wanting of an individual that correctly judges that an outcome will not be pleasurable, but decides to pursue it anyway. Often this is the situation experienced by addicted individuals: irrationally they want the drug even if then they are disappointed because the reward could not live up to their high expectations (error in judgement) or they do not have a hedonic experience during the consumption of the drug. In this case, there is a clear dissociation between decision utility (the action to pursue a reward), predicted utility (the expectations or desires for reward) and experienced utility (the hedonic impact).

2.1.4 Neurological definition of the reward's components

Finally, liking and wanting are defined as neurological processes too. Liking is the result of the activity of small parts within the nucleus accumbens (NAcc), and ventral pallidum. These small parts are also called “hedonic hotspots” and need to be synchronized to work together. The liking system involves opioid neurotransmitters. Wanting is triggered by the activation in a single “wanting hotspot” that takes place in the mesolimbic dopamine system where the most prominent neurotransmitter is dopamine. Other neurotransmitters play a relevant role such as GABA, glutamate and opioids. This system englobes prefrontal neocortex, amygdala, parts of striatum, midbrain and the NAcc (Berridge and Robinson, 2003; Berridge, 2009).

2.1.5 Conclusion

In this chapter, reward concept, IST and four definitions of the reward system components have been presented. The four definitions help to better understand the reward components studied in neuroscience and psychology. However, the occasional inconsistencies within the different definitions can hinder our understanding of the IST and the correct operationalization of reward's components.

In the following chapter, we will present methods used to investigate the different facets of wanting and liking in human.
2.2 Wanting and liking measurements in human studies

IST test has been developed based mainly on research with non-human animals. Over the last few decades, researchers have applied IST paradigm to human. The neuroscientists and psychologists have investigated liking and wanting based on the mental process, effect and neurological definitions of these two components of reward system. Currently, the two biggest challenges in the concrete measure of liking and wanting in human are 1) the development of methods allowing to study the psychological components of the reward process in the correct unfolding cycle, and 2) the development of methods allowing to operationalize correctly the definition of different forms of liking and wanting; especially the operationalization of the “liking” and “wanting” definitions shared with non-human animals.

In the following chapter, we deepen the two challenges by presenting the research on the mental process definition of wanting and liking.

2.2.1 The correct timing to measure wanting and liking

In human, the first challenge in measuring wanting and liking is the development of methods allowing to study the psychological components of the reward process in the correct unfolding cycle.

According to Kringelbach et al. (2012), reward process goes through a cyclical time course: it starts with a phase of wanting (expectation of the reward), follows by a phase of liking (consummation of the reward) which can have a peak level of pleasure (e.g. a tasty meal, sexual orgasm, drug rush) and finishes with a phase of learning (where the organism learns and updates predictions of reward) (Figure 1).

![Figure 1](image.png)

**Figure 1.** Reward cycle adapted from Kringelbach et al., (2012). Y-axis corresponded to pleasure in a potential situation. X-axis represented the time. Set-point corresponded to mood.
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THEORETICAL PART

The reward cycle (called also pleasure cycle) shows that pleasure is a dynamic process that have a start and an end and could not by continuously. All fundamental rewards have this type of pattern where one component is dominant compared to the two others.

According to the incentive salience hypothesis, the best moment to measure motivation (both cognitive incentives and/or incentive salience) would be before the reward consumption, since later in the hedonic experience, liking seems to be dominant. The best moment to measure hedonic impact (hedonic reaction and/or cognitive pleasure) is during or immediately after reward consumption. Learning should be measure at the end of the reward cycle where the expectations and experience of reward are compared and prediction of error are evaluated for future references. Experimentally, the presentation order of reward-associate cue and the timing of measurement are important. If the measurements are not done at the right moment, other processes can be measured instead of motivation and hedonic impact. To study incentive salience, the incentive cue (reward or reward-associated cue) must be presented before the instrumental action and the measurement should be done at this specific moment. If the incentive cue is presented after the instrumental action and the measure of “wanting” is done during the instrumental action (that means before the presentation of the reward associated cue), what would be measured is a reinforcement learning. In fact, to measure “wanting”, it is important that the individual does not learn a contingency between the instrumental action and the reward or reward-associated cue. To study conscious pleasure, the measurement should not be done too far away from reward consumption, otherwise it may risk measuring encoded memory of the pleasurable experience instead of liking.

When measuring wanting and liking, physiological state of an individual at specific moments in time is of major importance. In the IST, the interaction between the internal state of an organism in a specific moment and the environment is crucial. The reward process is influenced by the interaction between the organism’s physiological state (e.g. hunger/satiation, thirst, drug craving, stress) or the brain state (e.g. changed in the dopamine level) and the elements present in the environment (e.g. reward-associated cue) (Berridge & Doherty, 2014; Pool et al., 2016). In fact, a relevant physiological state increases the CS perceptual salience and it will then acquire the capacity to attract attention. Two examples are the hunger state that make food more desired and pleasurable (Cabanac, 1971), or the satiety state that can dampen the pleasure for a specific food after having eaten it until satiety.

2.2.2 The correct operationalization of wanting’s and liking’s definitions

Over the years, several methods have been developed to study the different subcomponents of the reward process. In animal research, “liking” is measured by collecting affective orofacial reactions (e.g. licking, gaping) and “wanting” through conditioned approach, auto-shaping and effort measures. “Learning” can be measured through Pavlovian conditioning and instrumental reinforcement.
However, measuring the dissociation of these components in human is still under investigation, and several issues exist because it is not possible to directly extend the animal models to human research. In fact, humans, for example, can fake facial expressions and inhibit consummatory impulses (Tibboel et al., 2011). In humans, two additional facets in addition to “liking” and “wanting” components of animal model can be measured. Thomsen et al., (2015) presented the current methods used in humans, to measure liking, wanting without quotation marks and “liking”, “wanting” with quotations marks. Liking without quotation marks can be measured through subjective rating or verbal report of pleasure, the Fawcett-Clark Pleasure Scale (FCPS; Fawcett et al., 1983), the Snaith-Hamilton Pleasure Scale (SHAPS; Snaith et al., 1995), the Michigan Wanting and Liking Questionnaire (MWLQ; Berridge et al., 2010). Wanting without quotation marks is often measured through subjective rating, verbal report of desire, the Michigan Wanting and Liking Questionnaire (MWLQ; Berridge et al., 2010) and the Sensitivity To Reinforcement of Addictive & other Primary Rewards (STRAP-R; Goldstein et al., 2010) questionnaires. Learning without quotation marks can be assessed by rational inference tests and verbal explanations.

Concerning “liking” component, it is assessed by examining brain activity in hedonic hotspots when a participant consumes a reward or by hedonic reactions objectively measured by emotional facial expressions (Steiner, 1973; Berridge, 2000; Smith, Mahler, Peciña & Berridge, 2007; Berridge & Kringelbach, 2008). In addition, heart rate (Thomsen et al., 2015) and rectal pressure variability (for sexual pleasure) (Georgiadis et al., 2006) are other “liking” indicators in human. “Wanting” can be measured through conditioned approaches, incentive key press/force grip tasks, and effort expenditure for reward tasks. Likewise, “learning” can be measured through subliminal instrumental tasks, and response bias reward problem tasks.

In addition to the above measurements, several scientists developed supplementary methods to measure the four forms of motivation and hedonic impact in human. In the following chapter, a presentation of experiments measuring wanting and liking will be proposed. In the first part of the chapter, experiments assessing liking and wanting followed by experiments assessing “liking” and “wanting” will be presented. Then, issues related to liking and wanting definitions will be presented. Finally, the current state of the topic in chemosensory field will be highlighted.

2.2.2.1 Methods to assess liking and wanting

Explicit liking and wanting seems to be easier to operationalize and measure compared to implicit facets. Several studies dissociated explicit facets of liking and wanting in normal, pathological population to study food (Hutchings et al., 2017; McNeil et al., 2017; Ramaekers et al., 2014 b, c; Lambert et al., 2006), drug (Volkow et al., 1997, 1998, 1999, 2002, 2003, 2004, 2006), alcohol intake (Rueger et al., 2015; Hobbs et al. 2005; Fox et al., 2002) and sexual behaviours (Kang et al., 2016;
Lippa, 2006, 2007). Recently, methodology have been applied to study wanting and liking in children too. Often, the visual analogue scale (VAS) is applied to measure explicit liking and wanting. Typical structure of the sentence is the following: "how much do you like/want (...)". An example of this kind of methodology is used by Goldstein et al. (2010) in cocaine-addicted (mean abstinence of 2 days) and non-cocaine addicted individuals (controls) where they performed a behavioural and a tomographic (PET) study. Concerning the behavioural part, authors dissociated experimentally wanting from liking for multiple rewards, contexts and under the effect of medicaments. They devised STRAP-R (Sensitivity To Reinforcement of Addictive and other Primary Rewards) questionnaire to evaluate wanting and liking for expected “drug” rewards as compared to primary non-drug rewards (food, sex and alcohol). For liking, subjects rated “how pleasant would it be to eat it (food), do it (sex) or use/drink it (drug/alcohol)”. For wanting, subjects rated “how much do you want to eat it (food), do it (sex) or use/drink it (drug/alcohol)”. A five-point Likert scale (from 1-“somewhat”, to 5-“extremely”) was used to answer. The same questions were repeated for three different situations: “current”, “in general”, and “hypothetically while under drug influence” of their favourite reinforcer. Sixty minutes before the administration of the STRAP-R, participants received an oral dose of the dopamine agonist methylphenidate (20 mg) or placebo (100 mg dose of thiamine) to influence wanting component by increasing dopamine level in the brain. Then, participants participated to a positron emission tomography (PET) in which they performed tasks consisting of solving arithmetic problems (controls) or watching neutral or cocaine-related videos (cocaine-addicted subjects) while their brain activity was recorded. Behavioural findings showed that only addicted individuals gave a different value of the three expected reinforcers in the different contexts. Precisely, wanting and liking ratings of drugs were higher compared to the ratings of food, in a situation “under drug” influence. In “general” or “current” situations, the pattern was reversed: the highest liking and wanting value was given to food (in current) and to sex reinforcers (in general situation) compared to drug. Interestingly, under methylphenidate, authors found a dissociation, in addicted individuals, between explicit liking and wanting: participants reported higher wanting drugs compared to liking drugs in recalling drug-related situations, revealing that addicted individuals wanted drugs even if they did not like them once they consumed them.

However, these questionnaires on wanting and liking are not without issues, because they can be affected by demand characteristics and subjects can confuse pleasure with motivation (Robinson & Berridge, 1993). In fact, individuals that are not expert on the wanting and liking terminology, can easily say that what they like is also what they want and there is no difference in the two terms. A practical example is the experiment of Kiildegaard et al., (2011) in which they investigated the explicit wanting, explicit liking, and preference for sourness (apple juice and fruit drink) in children (9-14 years old) by means of adapted rating methods. Children received two servings: 1) four samples
of yellow apple juice (150 ml each) and 2) four samples of red fruit drink (150 ml each) served in transparent cups at room temperature. Then, they evaluated preference, sourness perception, liking and wanting. Wanting and liking were evaluated through a 5-point facial rating scale (from 1- “least liked/least wanted (sad face)” to 5-“most liked/most wanted (smiling face)”. Wanting was explained as a desire, “a feeling of how much they fancy the juice or fruit drink right now” (Kildergaard et al., 2011, p. 622). However, the term “fancy” is subject to interpretation. In the dictionary, it is simultaneously defined as adjective for something that “require skill to be performed”, and as an “irrational liking for” something as well. In addition, children could have their own interpretation of “fancy” that does not necessarily correspond to the IST definition of explicit wanting.

Limitations of explicit methods
To conclude, by using questionnaires and VAS, the risks are multiple: subjects do not know their correct use and can make errors, can interpret the terms used according to their knowledge or give answers in a manner that will be viewed favourably by the experimenter and without giving their real preferences and motivations (social desirability bias).

2.2.2.2 Methods to assess “liking” and “wanting”
Regarding the concepts of “liking” and “wanting”, the operationalization is even more difficult compared to the explicit operationalization. The main reason is that these two components are not directly subjectively experienced and consequently they cannot be measured by direct procedures.

Computerized facial expressions techniques
In recent decades, computerized facial expressions’ techniques based on the Facial Action Coding System (FACS of Ekman & Friesen, 1978) or adapted version for facial expression in babies (such as the BABY FACS of Oster, 2004) have been used to evaluate the “liking” for specific foods. In addition to other measures of liking without quotation marks (maternal ratings, researcher judgements) and “liking” (video coding of body gestures, mouth movements indicating approach or avoidance, vocalisation, skin temperature, eye movements and regulation of respiration), facial expression analysis help to improve levels of description and explication. An example of the adaptation of this methodology is presented in Hetherington et al., (2016) study, to assess liking and “wanting” of infant during the feed. The authors developed a coding tool (The Feeding Infants: Behaviour and Facial Expression Coding System- FIBFECs). Based on previous literature, they selected seven action units from the BABY FACS to measure effective response to food: inner brow raised (AU1), brow lowered (AU4), squinting (AU7 extreme), nose wrinkling (AU9), upper lip raised (AU10), lip corners down (AU15), and gaping (AU26/27). Important, authors decided to use actions
units only as indicators of “disliking” but not “liking”, because several studies reported that facial expressions are more suited to measure disliking compared to liking (Mennella et al., 2001; Rosenstein & Oster, 1988; Zeinstra et al., 2009). “Wanting” was measured through two behaviours inside the avoidance/approach tendencies: (i) leans forward/reaches for food/puts spoon voluntarily in his/her mouth, (ii) rate of accepting the spoon offered (in spatial rather than strictly temporal terms). Four levels of rate of acceptance were identified going from three to zero: early acceptance (the opening of the mouth when the spoon was at a distance to the mouth), late acceptance (when the spoon was close to the mouth), enforced acceptance (when the lips were touched with the spoon) and refusal. Lower scores on the total scale indicated greater “wanting” and/or “liking”.

Limitations of computerized facial expressions methods
Despite the added values of these techniques that can be used with infants (that cannot speak) and with adults without asking directly their preferences and motivations to obtain a product, they have some limits. First, an intensive and long training of the coders is required to learn the multiple combinations of the FACS action units. Second, a well-defined glossary without any source of ambiguity in the terms used in coding scheme should be created. Finally, coding and data analyses (in which coding sheets of multiple coders are compared) are very time consuming too.

Implicit techniques
Based on the IST’s assumption that “wanting” and “liking” are automatic processes, another potential way to assess them is by means of implicit measures. Implicit measures are “measures that assess automatic evaluations without a person’s knowledge of what is being assessed” (Briñol, Petty, & McCaslin, 2009, p. 285). Currently, most implicit measures are automatic in the sense that they are based on mechanisms that are less easy to control and less intentional compared to explicit measures. The main advantages of implicit measures compared to explicit measures are that the former might capture mechanisms that are not introspectively accessible. Consequently, they are less consciously controlled and less susceptible to extraneous factors (e.g. social desirability, deception). On this basis, several implicit measures have been adapted to measure these two implicit components such as the Stimulus Response Compatibility Test (SRC; De Houwer, 2003), the Affective Simon Task (AST; De Houwer & Eelen, 1998), the Approach/Avoidance Task (AAT; Rinck & Becker, 2007), and the Implicit Association Test (IAT; Greenwald et al., 1998). The assumption at the core of these tasks is that for an individual it is easier to make approach-movements toward a rewarding stimulus than to avoid it. Avoidance or approach tendencies are inferred on the relative speed with which participants move toward the stimuli by using a manikin in the SRC and the AST or by moving a joystick in the AAT. Important, participants are never asked to make any explicit judgment on the stimuli.
presented. Particularly, Stimulus Response Compatibility Test and Affective Simon task are variates of the Simon task (Simon et al., 1969) consisting of a test showing that reactions times are faster and participants answers are more accurate when stimuli and response occur in the same relative location (Simon effect or stimulus-response compatibility effect). For instance, participants watch at the screen a red triangle and a blue one that can appear at the right or at the left of the screen. Then, they are asked to press the key A as quickly and as accurately as possible each time that they watch the red triangle and the key B each time they see the blue triangle, but regardless of the location of the stimulus. In congruent trials, the button to be pressed is on the same side as the stimulus. In incongruent trials, the button to be pressed is on the opposite side to the stimulus. Normally, participants are faster and more accurate in congruent trials (Simon effect). In the affective Simon task, positive, negative and neutral words are used as stimuli and the effect of affective meaning is evaluate on the reaction times and on the accuracy of the answer. In Approach/Avoidance Task (AAT), participants are asked to respond as quickly as possible to pleasant and unpleasant stimulus by pushing or pulling a joystick. Normally pleasant stimuli provoke automatic approach behaviors (pulling the joystick through the stimuli) compared to unpleasant stimuli that produce avoidance behaviors (pushing the joystick away from the unpleasant stimuli).

An example of application of SRC and of the AST, is the experiment of Field and co-workers (2011) that replicated the findings found in another study from 2008. They developed an SRC and a modified version of the Simon task to investigate approach and avoidance tendencies in heavy social drinkers. The SRC findings showed that heavy drinkers had a stronger approach bias toward alcohol. However, the modified version of the Simon task did not show the same results. Authors concluded that the Simon task was not sensitive enough to capture motivational processes in addiction compared to the SRC task. However, other researchers found opposite results using the same methodology (the SRC task) in addicted population (Barkby et al., 2012; Spruyt et al., 2013). An example of the AAT is the study of Cousijn et al. (2013). The aim of this study, was to understand the cannabis approach bias before and after cannabis use. In a real-life setting (coffee shops), participants were asked to perform a variant of AAT. In the first group, heavy cannabis users performed the AAT while they had the intention to smoke but before they smoked cannabis; in the second group, heavy cannabis users were tested after they had smoked cannabis. The AAT consisted in presenting participants with several images of cannabis or of neutral subject. Participants were asked to use a joystick to pull (approach) or to push (avoid) images in response to their rotation direction. The images were presented with a rotation of three degrees to the left or to the right. In one group, the participants received the instructions to push images rotated to the left and pull images rotated to the right. In the second group, the experimenters gave the opposite instructions. The action “to pull” resulted in an increase of the image’s size and the action “to push” resulted in a decrease of it. However, the findings were not in
line with the IST arguing an implicit bias for cannabis in both groups. The first group showed higher levels of subjective craving and lower levels of satiation, but did not have implicit bias in the AAT. The group who had just smoked cannabis had positive AAT scores, revealing implicit bias for cannabis. Other similar AAT designs have been used in Sharbanee et al. (2013) that found results in line with IST’s predictions, or in Wiers et al. (2013) that did not found results in line with IST’s predictions.

Another implicit measure used to measure “wanting” and “liking” is the Implicit Association Test (IAT). The first IAT was developed by Greenwald et al. (1998) to capture associations between targets and attribute concepts. In a typical IAT, first, participants are asked to categorize a target stimulus into one of two target categories (e.g., “flowers” or “insects”). In a second time, participants need to classify attribute stimuli as referring to one of two attributes (e.g., “pleasant” vs. “unpleasant”). They need to use the same keys to answer the two tasks, during which their reaction time is measured. The stronger automatic association in memory is reflected by the fastest pairings.

Typically, participants are faster when stimulus-response assignments are compatible with associations in their memory: press the same key for “flowers” and “pleasant” and another for “insects” and “unpleasant”. It is assumed to be an implicit measure, because it is difficult to control and because participant are not asking to adapt their response speed according to the strength of association of the two concepts. By simply changing the labels and stimuli, several variants of this classical version have been developed to measure the implicit and automatic facets of human attitudes. Several studies used this methodology (Koranyi et al., 2017; Tibboel et al., 2015; Dickson et al., 2013; Dai et al., 2010; Aharon et al., 2011; Tibboel et al., 2011; De Houwer & De Bruycker, 2007; Wiers et al., 2007b; De Houwer et al., 2006; McCarthy & Thompsen, 2006; Dewitte, 2005; Robinson et al., 2005; Jajodia & Earleywine, 2003; Palfai & Ostefin, 2003; Wiers et al., 2002; Swanson et al., 2001). For instance, Tibboel et al. (2011) created two separate IAT tasks (a “wanting” IAT and a “liking” IAT) to investigate “wanting” and “liking” in smokers. Authors used nicotine related words and not nicotine related words as categories. To test “liking”, the authors used a valence IAT (Wiers et al., 2002) and substituted the term “positive” and “negative” with the labels of “I like/ I do not like”. To measure “wanting”, a variant of the arousal IAT (Wiers et al., 2002) was used by changing the labels with “I want/ I do not want”. Participants were tested after 12h of nicotine deprivation and immediately after smoking. Findings showed that smokers had more “liking” for nicotine when they were deprived compared to when they were satiated. In addition, they had more “wanting” and liking for nicotine compared to control group.

An interesting IAT apply to investigate sex differences in women and men was used by Dewitte (2015). The author also used a variant of the IAT (the personalized single category, SC-IAT) to study “liking” and “wanting” for sexual stimuli. The personalized IAT was created by Olson and Fazio in
2004 to avoid any influence of extra personal associations such as for example societal stereotypes. To avoid any confusion between participants’ own attitudes and societal norms, the authors changed the label “positive” and “negative” with the more personal label of “I like” and “I don’t like”. In the Dewitte study, the authors decided to use a variant of the IAT because they considered the traditional IAT to be more closely related to the concept of “liking” than to the one of incentive value, and they were interested in measuring both components. To induce a motivational state for sexual stimuli, participants were primed with one of three film clips: an explicitly sexual, a romantic, and a neutral film clip. Participants watched the film clips before the “liking” IAT, and again before performing the “wanting” IAT. In “liking” IAT the word sex and the labels “I like/ I don’t like” were used. As stimulus material, five positive (i.e., gift, vacation, laugh, summer, entertain) and five negative (i.e., pester, extort, loneliness, distress, war) words were presented for the evaluative dimensions. For the “wanting” IAT, the word sex and “I want/ I do not want” labels were used. For stimulus material, five verbs referring to “wanting” (i.e., desire, wish, approach, crave, long for) and not “wanting” (i.e., avoid, avert, ward off, stop, prevent) were selected for the study. In addition, five words related to sex were used for the object dimension in both “liking” and “wanting” tasks (i.e., fuck, make love, arousal, intercourse, and orgasm). Findings showed that, women and men differed only at their desire to engage in sexual activity (i.e., “wanting”) but not in the experience of pleasure (i.e., “liking”). These differences in “wanting” varied according to the context primes where romantic condition highlighted a major “wanting” for sex in women.

Limitations of implicit methods

Although, researchers found significant results by means of the AAT, SRC, AST and IAT methodologies, other scientists question the validity of these methods. For instance, Eder and Rothermund (2008) argued that the AAT is driven by the valence of stimulus used in the test. In fact, if positive stimuli are used in the test, it is normal that the participant will adopt approach behaviours and vice-versa. Moreover, Krieglmeier et al. (2013), argued that the AAT effect occurs mainly when the participant understands the goal of the task and not when he is unaware of it (as in the case of the “wanting” component). Concerning the IAT, while implicit association tests offer a method of choice to investigate “wanting” and “liking”, they suffer from a critical drawback: the labels’ choice. The labels “I want” and “I do not want” used in the wanting-IAT task englobes a hedonic content implying that the implicit association tested is at best, a mix between “liking” and “wanting”. In addition, in some wanting-IATs the authors claim to measure the “wanting” concept, but often measure the psychological concept of arousal instead (Wiers, 2001). Moreover, in the approach-avoid IAT, the behavioural disposition is captured though mental processes of incentive salience or cognitive salience are not. Concerning, the valence-IAT, the labels “positive” and “negative” do not
have the same meaning as the labels “liking” or “disliking”. Positive and negative are adjectives that can be related to many generic words. However, the concept of “liking” can be related only to pleasure, to hedonic experience. In addition, L-IAT captures the memory based pre-representations of a reward and not the hedonic reaction during or just after reward consumption (Tibboel et al., 2015). According to that, we cannot conclude with certainty that L-IAT measure “liking”. Moreover, in the different variants of the IAT, very generic positive and negative words are used with the risk that the interpretation vary from an individual to another. Probably, to simplify the task, participant will do a personal mental association of these words as positive or negative words and not as liked or disliked words (as the way that is defined by the IST).
2.2.3 Inconsistency in wanting and liking definition

A final issue in the study of reward system is an inconsistency in the interpretation of the four facets of motivation and hedonic impact. From the first to the last definition of the reward components, Berridge and co-workers published several articles where they changed these theoretical definitions. These modifications based on empirical research over more than 30 years increase our knowledge on the reward process but increase the confusion of the final definitions to operationalize. For instance, liking in the IST was defined as an experience of pleasure and accordingly, the measurement should be done during or immediately after reward consumption (see section 2.2.1). However, in some studies, researchers claimed to measure explicit liking by asking participants to report their expectancies of pleasure, to remember or imagine how much they liked or would like a pleasant stimulus and without even presenting the reward to be consumed (e.g., Born et al., 2011; Bushman, Moeller, Konrath, & Crocker, 2012). This kind of procedure is not in line with the IST and should not be considered as correct to measure explicit liking, because it measures memories of liking and not the experience itself. The same procedure is used to measure, sometimes, explicit wanting (Leyton, 2002). According to Pool meta-analysis (2016), the confusion on how to measure the psychological components of the reward system, could in part be related to the concept of expected pleasantness. The authors found that in 84 studies examined, 25% of them measured expected pleasantness to reflect liking concept and 13% to reflect wanting concept. However, expected pleasantness refers to the expectations of how pleasant or not something is going to be. It is an evaluation of how good or how bad a specific reward is going to be and it did not correspond to any of the four facets of wanting and liking components. It represents the mechanism underlying cognitive desires and relies to a motivational system called goal-directed system different for instance from the Pavlovian system of the “wanting” component (Berridge & Aldrige, 2008). Experimentally dissociate liking, wanting and expected pleasantness would be useful to prove evidences to Pool’s suggestion.

2.2.4 Debate on the necessity to dissociate “wanting” from “liking” in chemosensory research

“Wanting” and “liking” have been studied in reference to food research. The literature in the field gives ambiguous results mainly due to incorrect interpretations and operationalization of the implicit components’ definitions in the IST theory. For instance, Havermans (2011) claimed the usefulness to separately study “liking” from “wanting” in the reward process with respect to food consumption. He argued that investigating the contribution of true “liking” and true “wanting” to the experience of food requires to objectively measure these food reward components, but “liking” and “wanting”
typically (in normal food intake) occur quasi-simultaneously and research does not need to find a way to measure them separately. In 2012, he argued that given the current theory and data in food research, it is not possible to differentiate these two psychological components in human with validated methods. The desire to develop new and more efficient methodology provoked an inconsistency in the operationalization of these two concepts. Often, the construct operationalization is not in line with the incentive salience assumptions (Havermans, 2011, 2012; Pool et al., 2016). Havermans presented the example of Lemmens et al. (2009) experiment: the authors developed a computer task where they separately measured liking (with a rating task) and “wanting” (with a memory task). To assess the sensitivity of the computer task in detecting changes in “wanting” and liking after food consumption, the participants performed the tasks before and after the meal. In the liking task, participants were presented with two food items and had to rate which one of the two presented items they liked the most. The “wanting” task comprised of finding matching pairs of food pictures in a 5 X 5 grid memory task. According to score obtained in two tasks, participants received a fixed amount of chocolate mousse or cottage cheese to eat (rewards). In a second time, they performed the tasks twice again in separate sessions, once for the chocolate mousse and once for the cottage cheese. The authors found a higher decrease in “wanting” for participants that highly liked and ate chocolate mousse compared to the participants that ate the cottage cheese. However, in this experiment we can’t argue that the task of “wanting” really measured this component. In fact, by measuring “wanting” through the performance of a memory task, the “wanting” result can rely to memory processes instead of motivational ones (Havermans, 2011).

In response to Havermans (2011), Finlayson and Dalton (2012) presented several studies in which implicit components in food reward processes were operationalized and measured. Finlayson and Dalton, claimed the limited value of Havermans’ article due “to the lack of systematic criteria for study inclusion or exclusion. The resulting analysis is unfortunately based on a small number of confirmatory or otherwise flawed examples and gives an overly pessimistic interpretation of a field that holds a great deal of potential” (Finlayson and Dalton, 2012, p. 373). The two authors argued that the main error in Havermans (2011) and current literature in “liking” and “wanting” is that they considered them as two physical realities “subject to detection by the right set of methodologies” (Finlayson and Dalton, 2012, p. 374). However, it is important to take in mind that they are two theoretical constructs and intangible concepts, consequently they cannot be directly measured but only operationalized. “The success of the chosen methodology will then depend on the transparency and plausibility of the relationship between the operational definition and the conceptual framework from which it is derived” (Finlayson and Dalton, 2012, p. 375). Authors presented several food studies in which reliable and transparent methodology with good construct validity has now allowed to differentiate “liking” and “wanting” in humans too (see Finlayson and Dalton, 2012 for a full and
2.2.5 Conclusion

In this section, we presented the state of the art on the multiple methods used to investigate the different facets of wanting and liking in human. The operationalization of explicit facets seems easier to be done compared to the operationalization of the implicit facets. In fact, “wanting” and “liking” can’t be directly subjectively experienced and consequently they cannot be measured by direct procedures. Limitations of explicit measures as well as limitations of implicit measures were highlighted. Explicit methods risks are mainly related to misunderstanding of the wanting and liking terms and social desirability bias.

Computerized facial and vocal expression methods are high demanding in glossary conceptualization, training and coding. Implicit techniques such as the IAT have label issues with the consequence that often what it is tested is a mix between “liking” and “wanting” instead of a pure measure of each concept.

In addition, the multiple articles existing in the literature show an inconsistency in the interpretation of the four facets of motivation and hedonic impact with the consequence of adding a supplementary issue in the operationalization of the components.

Finally, more specific research on food reward highlighted the necessity to find common valid methods to be used to investigate wanting and liking in food intake domain.

In the following chapter a promising method, to measure “wanting”, the Pavlovian-to-Instrumental Transfer (PIT), will be presented.
2.3 Pavlovian to Instrumental Transfer Paradigm (PIT) as a measure of “wanting”

Several methods have been developed to experimentally measure how predictive cues influence and guide our actions, and more specifically understanding better the rewards' components in humans. Among the different methods, the Pavlovian-to-Instrumental paradigm provides a pure measure of the effort engaged to obtain a reward (“wanting”) independently of liking component and without asking explicitly the cognitive desire that pushes the participant to obtain a reward. This paradigm includes two separate conditioning phases (Pavlovian and instrumental) followed by a test phase in which the effect of the Pavlovian cues on the instrumental action is assessed (transfer test).

2.3.1 Pavlovian and the instrumental conditionings

To understand Pavlovian-to-Instrumental Transfer effects, it is essential to understand the two learning processes at the core of the PIT concept: the Pavlovian and the instrumental conditionings. The Pavlovian conditioning is a learning procedure in which a “neutral stimulus becomes a conditioned stimulus (CS) by pairing its occurrence with an unconditioned stimulus (US) that naturally elicits some responses” (Cartoni et al., 2016, p. 4). In most positive Pavlovian tasks, a sound is used as conditioned stimulus and it is paired with a biological potent stimulus such as food (US). The organism learns that the delivery of a food (US) is always concomitant with the earliest presentation of the sound (CS). Consequently, the organism learns an association where CS predicts US. The result of the positive conditioning is that the animal or participant will approach the side of the food delivery as soon as he hears the sound.

Instrumental conditioning is another type of learning procedure in which an organism learns that an action delivers a reward or a punishment. In this conditioning, the strength of a behaviour is modified by the behaviour’s consequences. The most common example is the one of a hungry rat who, after a period of training, correctly learns to press a lever to receive food. The instrumental conditioning can be divided into two types: goal-directed actions and habitual actions. Goal-directed actions are controlled by response-outcome (R-O) associations: the associations are controlled by the consequences of action (or goal-directed actions). For instance, through the formation of action-outcome (A-O) associations, the rat learns that pressing a lever gives food. Habitual actions are controlled by stimulus-response (S-R) associations: antecedent stimuli control the instrumental behaviours through the formation of stimulus-response (S-R) (Balleine & Dickinson, 1998). Habits persists even if the outcome value changed and the reward becomes less attractive, because the habitual control of instrumental behaviour emerges gradually with repeated performances. In habitual behaviour, the value of an outcome has become fixed and does not affect behaviour anymore. An example of this, it is alcohol consumption. Researchers in this field claim that even if drinking is
associated with aversive consequences, such consequences do not alter the performance of the action itself. Habits can be seen as the no-pathological intermediate stage before the development of compulsivity (Everitt & Robbins, 2005).

2.3.2 Development of the PIT concept

At the beginning of learning process investigation, Pavlovian and instrumental conditionings were not clearly differentiated. Later, these two types of conditionings were separated, and transfer effect was defined as the result of Pavlovian cues that generate appetitive or aversive emotional states (Cartoni et al., 2016). The PIT was initially used to study the influence of conditioned emotional responses (Rescorla & Solomon, 1967). Based on animal studies, subsequent researchers claimed that primary motivational processes could explain better transfer effects instead of emotional states (Bindra, 1974; Dickinson & Dawson, 1987). However, these motivational accounts did not help to explain how a Pavlovian cue could elicit an action tied to a specific outcome (specific transfer), but only as a general effect (Holmes et al., 2010; Cartoni et al., 2016). Further experimental studies increased the understanding of the instrumental learning process and in the 1990’s the instrumental conditioning actions were divided in habits and goal-directed actions (see chapter above for more details; Balleine & Dickinson, 1998; Balleine & O’Doherty, 2009; Balleine & Ostlund, 2007).

Currently, PIT concept refers to the ability of a Pavlovian stimulus (that predicts a reward) to enhance an instrumental action to obtain a reward (Estes, 1943, 1948; Kruse et al., 1983; Rescorla & Solomon, 1967). The PIT procedure is often used to investigate how cues control organism behaviours in activities such drinking, eating, and drug-taking (Everitt & Robbins, 2005).

The data on transfer effects are based mainly on non-human animals, such as mice (Crombag et al., 2008 a, b; Johnson et al., 2007; Mead & Stephens, 2003a, b; Sanders et al., 2007), rats (Balleine, 1994; Colwill & Motzkin, 1994; Corbit & Balleine, 2003; Delamater, 1995, 1996; Delamater & Holland, 2008; Edgar et al., 1981; Estes, 1943, 1948; Holland, 2004; Holland & Gallagher, 2003; Lovibond, 1981; Meltzer & Hamm, 1974a, 1974b, 1978; Meltzer & Brahek, 1970; Rescorla, 1994 a, b, 1997, 2000), monkeys (Henton & Brady, 1970), and pigeons (Herrnstein & Morse, 1957; Lolordo, 1971; Overmier et al., 1983). In recent years, the paradigm has been recruited to human research, both in healthy and pathological studies, to better understand the transfer effect from a psychological and neurological perspective (Bray et al., 2008; Talmi et al., 2008; Watson et al., 2014; Pool et al., 2015; Huys et al., 2016; Garofalo et al., 2015; Cartoni et al., 2015; Lewis et al., 2013; Nadler et al., 2011; Corbit et al., 2005; Hogarth et al., 2007; Pareded-Olay et al., 2002).
2.3.3 PIT paradigm

PIT paradigms are always composed of three phases: instrumental training, Pavlovian training, and a transfer test. The order of the two trainings can be changed without affecting the transfer effect. However, the length of the first or second phase modifies the amount of transfer (Holmes et al., 2010). In the instrumental training phase of an appetitive PIT, animals/participants learn the relationship between instrumental actions with positive or no outcomes. In the Pavlovian training, animals/participants learn to associate stimuli to the delivery of an appetitive outcome (CS+), of no outcome delivery (CSo), or of an aversive outcome (CS-). In the transfer test, the Pavlovian cues (CSs) are presented during the task. Participants are asked to perform the same actions learned during the instrumental training phase. The transfer effect occurs when the presentation of a CS+ produces more instrumental responses compared to when no CS (baseline) or CS- are presented. In some cases, no difference between CS+ and baseline had emerged even if differences between CS+ and CS- had been highlighted. These results could be due to response competition between instrumental and Pavlovian responses (see chapter 2.3.5 “Behavioural factors influencing PIT”). To avoid explicit training between CSs and instrumental actions, CSs are never presented with instrumental actions before the transfer test. The transfer test is usually run under extinction (without the presentation of the reward associated with the CS of the instrumental action) to avoid any explicit learning with the re-presentation of the reward.

2.3.4 Outcome-selective & Non-selective PIT paradigms

PIT paradigms can be divided into outcome-selective or no-selective procedures according to the type of transfer effect. Transfer effects can be divided into general and specific forms, each based on a specific neural substrate. Specific transfer is related to the capacity of a “cue to enhance specific actions associate with the same outcome as the cue, whereas general transfer refers to the ability of a cue to enhance also actions paired with different outcomes” (Cartoni, 2016, p. 6). In PIT studies, specific transfer effects are referred to the outcome-selective PIT procedures and general effects to the non-selective PIT procedures (Holmes et al., 2010). Both procedures are used with animals and humans according to the objectives of the experiment.

More precisely, in the first phase of the outcome-selective PIT, two stimuli (S1 and S2) are paired with two outcomes (O1 and O2). In a second phase, the animal/participant is trained to perform two different types of responses (R1 and R2) to obtain the outcomes (O1 and O2). In the test phase, the presentations of S1 should induce a response associated with O1 more than a response associated with O2, and vice versa when the S2 is presented.
Concerning the non-selective PIT procedure, in the first phase, a CS+ is repeatedly paired with an outcome (O) and a CSo (neutral non-conditioned stimulus) or CS- (explicitly unpaired stimulus) with no outcome. In a second phase, the animal/participant learns to perform an action (R) to obtain this kind of outcome (O). In the test phase (conducted in the absence of the outcome), the learned instrumental action is assessed in presence or absence of the CS+ (but under extinction: no outcome is presented). During this phase, the presentations of CS+ should increase the rate of instrumental actions compared to the rate of instrumental actions during the presentations of CS- or of CSo. Thus, CSo presentation reflects only the facilitation of instrumental performance by the CS+; CS-, however, can reflect both facilitation of the instrumental action by the CS+ and suppression of instrumental action by the CS-.

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<tr>
<th>Pavlovian Conditioning</th>
<th>Instrumental Training</th>
<th>Transfer Test</th>
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<tbody>
<tr>
<td>S1 (\rightarrow) O1</td>
<td>R1 (\rightarrow) O1</td>
<td>S1: R1 &gt; R2</td>
</tr>
<tr>
<td>S2 (\rightarrow) O2</td>
<td>R2 (\rightarrow) O2</td>
<td>S2: R1 &lt; R2</td>
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</table>

Often studies used “full transfer paradigm” that can test both specific and general transfers. The procedure is the following: in a first time, two instrumental actions deliver two different outcomes (e.g. food pellet vs. sucrose). In a second time, three CSs, two paired with the outcomes delivered by the instrumental actions and one paired with a third outcome. Finally, in the test phase, both specific and general effects can be observed. The specific transfer effect occurs if the CS paired previously with the same outcome provoke the instrumental action sharing the same outcome. The general transfer effect occurs if the third CS paired with a third outcome (that was not paired with an instrumental action), provokes one of the two instrumental actions.

2.3.5 Behavioural factors influencing PIT

PIT can be influenced by multiple factors. These factors were highlighted from animal and human studies. Some of the principal features are presented in the following chapter.

1) Response competition between Pavlovian and instrumental learning processes
When a Pavlovian and an instrumental behaviour are simultaneously required, they can be in competition and the presence of one decreasing the effect of the other. The competition can positively or negatively affect the transfer effect as it can make transfer effects harder to detect. A typical example is a rat in a cage that learn first, that the sound of a bell is related to the presence of a rewarded food (Pavlovian conditioning) and, second, that after repeatedly conditionings pressing, the lever A delivers rewarded food (instrumental conditioning). The bell is the CS+ and normally it should elicit an instrumental response compared to a baseline (CSo). However, the requirement of Pavlovian and of the instrumental behaviours simultaneously responses can provoke a reduction of one of the two: lever pressing can compete with Pavlovian response and the animal can reduce the amount of lever pressing compared to the baseline.

In addition, Pavlovian extinction manipulation seems to play a role in the transfer effect, but this topic is still under discussion. In fact, the extinguishing Pavlovian response plays an important role in eliciting transfer (Holmes et al., 2010) and a long Pavlovian extinction might positively affect transfer too (Cartoni et al., 2016). However, this is not always the case and the transfer effect could be unaltered in extinction of Pavlovian response (Delamater et al., 1996) or negatively influence the intensity of transfer (Lovibond et al., 2015).

The extent of the competition between Pavlovian and instrumental learning response might also depend on the type of CSs. According to Tomie (1996), a diffuse CSs (e.g. a sound) produces a stronger transfer compared to discrete CSs (e.g. a light). The reason behind this is that diffuse CSs provoke less evoke sign-tracking, and consequently less competition. Finally, the spatial location of the instrumental response manipulandum plays an important role in the competition between Pavlovian and Instrumental learning responses. However, if the CSs is located proximal to the instrumental response manipulandum, discrete CSs produce higher transfer compared to diffuse CSs.

2) The duration of the conditioning trainings phases

The duration of the Pavlovian and the instrumental trainings phases is important for their stabilization and consequently the development of the transfer effect. Regardless of the order of Pavlovian or instrumental trainings, whatever the phase 1 is (pavlovian or instrumental), if it is longer than the phase 2 the transfer effects seemed to be positively influenced. If phase 2 is increased compared to phase 1, the transfer effect is negatively impacted (Holmes et al., 2010).

3) The duration and timing of the US-CS interval and of the CS presentation

Laurent & Balleine (2015) found an effect of the US-CS interval in transfer effects. A 0s delay between US and CS enhanced a standard transfer effect. However, a 10s delay provoked a “negative”
or a “reversed” transfer effect compared to 0s delayed condition. In mince, short intervals between CS (food) and US (sound) presentation produced strong conditioned reinforcement and no transfer. However, long intervals provoked strong transfer and no conditioned reinforcement (Crombag et al., 2008).

In addition, the CSs’ duration during the Pavlovian training phase seems also to influence transfer. In a rat experiment, Meltzer & Brahek (1970) used different durations of CS presentation: 6s, 12s, 40s and 120s. The findings showed that a short CS presentation provoked a suppression of the transfer and a long CS presentation enhanced the transfer effect. However, the experiments had no answer on why the rate have not remained high during the exposure to the 40s CS and only during the 120s. Further research should be done to highlight the reasons behind these results.

4) Type of instrumental response control systems

Early and later instrumental acquisition responses depend on two different systems. Early in time, the goal-directed system controls the action’s acquisition. In moderately trained rats (i.e., trained to press a lever to receive food), a reduction of lever pressing was found when the appetitive value of food was reduced (outcome devaluation). The same result was found when there was a reduction between the number of lever-presses and outcome delivery (contingency degradation). Later in time, the habit system plays a more relevant role. Rats over-trained on instrumental action (i.e., press a lever for food) were not influenced by outcome devaluation or contingency degradation, because habits were created and difficult to modify (Balleine & Dickinson, 1998a, b; Dickinson et al., 1995, 1998; Dickinson & Mulatero, 1989).

5) Duration in the reinforcement schedule between action and reward consumption

In rats, where they learned that pressing a bar gave food, Meltzer & Hamm (1974) found that shorter (90s) intervals between pressed bar action and food delivered produced a weaker transfer effects compared to longer (4min) intervals between the action and reinforced response, which instead provoked stronger transfer effects.

In addition, periods of instrumental extinction phase prior to transfer test positively influenced the apparition of transfer effects in the test phase (Dickinson et al., 2000).
6) Physiological state of the animal/participant

Manipulation of the hunger state by inducing devaluation\(^1\) via satiation eliminated general transfer, but did not have any effect on specific transfer procedure (Aitken et al., 2016; Corbit et al., 2007). Manipulation of stress level in humans by inducing an acute stress enhanced transfer effect (Pool et al., 2014) in “single lever” paradigms. This manipulation did not have any effect in animal “single lever” paradigms (Pielock et al., 2013).

Manipulation of the stress level by injection of dexamethasone at the end of the Pavlovian sessions in a specific procedure had negative impact of transfer effects in rats (Zorawski & Killcross, 2003). Morgado et al. (2012) found that rats under unpredictable chronic stress did not have deficits in Pavlovian and instrumental learning processes, but were impaired in PIT test phase where the transfer effect did not appear.

2.3.6 Neural substrates involve in transfer

Induced pathway disconnection lesions by the experimenter in rats showed that amygdala (Blundell et al., 2001; Hall et al., 2001; Holland & Gallagher, 2003), nucleus accumbens (Hall et al., 2001; Corbit et al., 2001; de Borchgrave et al., 2002), dorsal striatum (Corbit & Janak, 2007b; Pielok et al., 2011), midbrain structures (Murschall & Hauber, 2006; Corbit et al., 2007; Dickinson et al., 2000; Wassum et al., 2011; Wyvell & Berridge, 2000; Ostlund & Maidment, 2012; Soares-Cunha et al., 2012; Laurent et al, 2014), and prefrontal cortex (Ostlund & Balleine, 2007; Balleine et al., 2011; Bradfield et al., 2015; Scarlet et al., 2012) are involved in transfer effects. Specific PIT involves the basolateral amygdala and the nucleus accumbens shell. General PIT involves the central amygdala and the nucleus accumbens core (Corbit & Balleine, 2005, 2011). In human, fMRI studies highlighted the involvement of the same neutral substrates, particularly in the nucleus accumbens (Talmi et al., 2008; Mendelsohn et al., 2013), amygdala (Talmi et al., 2008; Bray et al., 2008; Prévost et al., 2012; Mendelsohn et al., 2013), and ventrolateral putamen (Bray et al., 2008; Prévost et al., 2012). However, a system-wide view of how these areas interact together to produce general and specific transfer is still not clearly defined (Cartoni et al., 2016).

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\(^1\)Devaluation is an experimental manipulation in which the US or the outcome valued is altered.
2.3.7 Pavlovian to instrumental transfer effect in human

The Pavlovian to instrumental transfer effect has been investigating and confirmed only recently in human. Currently, the PIT procedure has been used to understand how predictive cues influence and guide our actions in both normal and pathological populations. The human PIT designs can be adaptations of animal experiments or new paradigms such as “game-like” paradigms. Consequently, in the literature there are many variations of the PIT procedure, but they englobe always three phases: a Pavlovian conditioning, an instrumental conditioning and a transfer test phase. In the following chapter, a review of the PIT studies will be presented according to the type of paradigm and to the topic of investigation.

Analog of animal PIT paradigm

Analogue of animal paradigm adapted to human are common in the literature (Lovibond et al., 2015; Watson et al., 2014; Lovibond & Colagiuri, 2013; Nadler et al., 2011; Bray et al., 2008). Often the same primary rewards (such as food) are used and similar results are found between animal and human (Watson et al., 2014; Bray et al., 2008; Talmi et al., 2008). Sweet (i. e. chocolate milk, cola) and salty (i. e. chips, salty peanut) rewards are equally used in the human PIT literature. Lovibond & Colagiuri (2013) found that the presence of food-associated cues (as Pavlovian cues) enhanced instrumental action to obtain that specific food. Watson et al. (2014) found that food-associated cues interfered with goal-directed action even when the desire for a specific food was devaluated or participants were in a satiety condition.

Game-like paradigm PIT

New approaches employing “game-like paradigm” have been created to develop a more realistic procedure for participants and often abstract rewards are used (Paredes-Olay et al., 2002; Allman et al., 2010; Morris et al., 2014). A very interested example is the video game paradigm developed by Paredes-Olay and colleagues (2002), where the goal of the task was to defend Andalusia from navy and air force attacks. Before the transfer test, participants learned to associate two actions (two keyboard’s buttons) with the destruction of ships or planes (instrumental phase). Then, through a Pavlovian conditioning phase, participants learned to pair two figures with two outcomes (anti-aircraft or anti-boat torpedoes). Findings of the transfer phase showed that video game procedure was effective in producing a selective transfer effect. This kind of procedure allows to simplify PIT experimental design and to test transfer effect on young individuals too.
PIT and specific, general or aversive effects

In human, the presence of specific and general PIT effects has been confirmed only recently in the literature (Nadler et al., 2011; Lewis et al., 2013; Watson et al., 2014, Prévost et al., 2012). The studies can be differentiated in appetitive and aversive paradigms.

In aversive transfer paradigms, an aversive event is paired to neutral stimuli to develop aversive transfer (Rigoli et al. 2012; Lewis et al., 2013; Campese et al., 2013; Geurts et al., 2013; Huys et al., 2011). For example, Lewis et al. (2013) investigated the neural correlated of aversive specific and general PIT and the influence of aversive Pavlovian cues on instrumental learning through a computer game paradigm. They used a modified version from that used by Nadler et al. (2011). The goal of the video game was to defend a fictional kingdom against attacks of goblin, troll or ogre. Before the instrumental phase, participants performed a Sidman avoidance task in which the participant received an aversive stimulus (e.g. electric shock) at regular fixes intervals without a warning signal and reset after each avoidance response. The goal of the task was to investigate how individual learned to avoid shocks and demonstrate timings of their responses (Sidman, 1953). By means of the Sidman avoidance task, authors assessed negative reinforcement processes. During the instrumental phase, participants learned to associate two instrumental responses (pressing a specific button on a keyboard) with the avoidance of two distinct aversive outcomes (protecting with two imaginary shields from the various attacking creatures). During the Pavlovian phase, participants learned to associate coloured signals with different types of attacks. During the transfer test, Pavlovian cues were presented, and the instruction of the instrumental phase were given to the subjects. Behavioural findings showed a specific PIT effect: participants increased a specific instrumental response in the presence of a CS that signalled the same aversive outcome; and a general PIT effect: participants increased a learned instrumental response to avoid attack in a novel situation that they did not learned before. Neural findings showed an activation of corticostriatal circuitry (striatum and cingulate cortex) during specific and general PIT.

PIT and action specificity

Action specificity was study by means of PIT procedure too (Huys et al., 2011; Geurts et al., 2013a; Rosas et al., 2010; Gamez & Rosas, 2005; Hogarth et al., 2014; Hogarth & Troisi, 2015; Lovibond et al., 2015). For instance, Huys et al. (2011) developed a PIT design using withdrawal and approach behaviours to enhance transfer effect. This PIT design helped to study specific positive and negative effects (Huys et al., 2011), their brain regions of activation (Huys et al., 2011; Geurts et al., 2013a),

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2 Action specificity effect of the transfer is study by means of outcome selective paradigm where the effect of two CSs (each of it previously associated with different outcomes) is measured on instrumental action that delivered the same two outcomes paired with the CSs.
major depression (Huys et al., 2016), and serotonin level changes on transfer (Geurts et al., 2013b). Huys’ paradigm consisted in using two contro-balanced blocks: an approach and a withdrawal block. The transfer paradigm included both appetitive and aversive CS’s and instrumental responses consisted of either approach or withdrawal from stimulus. During the instrumental phase, participants ran an approach or withdrawal task according to the block. During the approach block, subjects decided if they wanted to collect mushrooms. To collect them, they had to move a mouse toward the mushroom and click on them (approach-go). If they did not want to collect mushroom they had to abstain from response (approach-no-go). In the withdrawal block, the task was different. Participants had to decide if they wanted to discard mushrooms (withdrawal-go) or do nothing (withdrawal-nogo). According to their action, an outcome (monetary reward) was presented at the screen. An auditory reinforcement informed participant on the correct answer. During the Pavlovian training, participants learned to associate fractal visual stimuli and tones with monetary outcomes. In the extinction Pavlovian-instrumental transfer phase, they were asked to choose between collecting or discarding mushrooms, as in the instrumental training phase. With this procedure the authors were able to show transfer effects of appetitive and aversive cues. These results were replicated by Huys et al. (2016) for healthy individuals in an experiment where transfer effect on depressed patients were also tested. The same paradigm of Huys et al. (2011) was used in healthy and depressed patients. Interestingly, on depressed patients the results were different: patients with depression did not have action–specific effects of Pavlovian cues during the PIT compared to the control group. The opportunity to obtain or to lose rewards according to the type of action performed did not influence the actions of depressed patients. This insensitivity to rewards and losses in the PIT task proportionally decreased to the improvements during the following months.

**PIT and individual differences**

Individual differences seem to play an important role in transfer paradigms (Garofalo & di Pellegrino, 2015; Sebold et al., 2015). Garofalo & di Pellegrino (2015) investigated the individual differences in the propensity to approach and engage cue-predicting reward in an appetitive human PIT. Based on animal literature, authors categorized individuals according to their learning styles: Sign-Trackers (ST) and Goal-Trackers (GT). The authors defined the two learning styles as follow: ST attributed more incentive salience to Pavlovian reward-associated cues compared to GT. The consequence was that they engaged more rapidly in approach behaviours. ST individuals seemed to be more vulnerable to addiction and impulsivity. During the pavlovian phase, eye-movements were recorded to characterize participants as ST or GT. During the instrumental phase, participants learned to associate specific responses (left or right squares) with a rewarded outcome (monetary) or a no-rewarded outcome, respectively. During the task, participants had to choose between left and right squares to
gain a reward. They indicated their decision by clicking the appropriate square. They were free to perform as many choices as they wished. During the Pavlovian phase, participants learned to associate fractal images with monetary reward or no-reward (light-yellow circle). Results showed that ST individuals tended to direct contiguous eye-gazes towards the cue (CS) and GT individuals tended to direct contiguous eye-gazes towards the location of reward delivery (US) even if it was not available because CS was still at the screen.

**PIT and neuropsychiatric disorders**

PIT paradigms were used to investigate neuropsychiatric disorders such as schizophrenia (Morris et al., 2014), anxiety-depression (Huys et al., 2011; Quail et al., 2016; Huys et al., 2016), addicted and normal drinkers and smokers (Garbusow et al., 2014, 2015; Hogarth et al., 2014; Martinovic et al., 2014), and in relation to some negative human behaviours such as aggression (Geurts et al., 2013). For instance, Garbusow et al., (2014) studied the transfer effect on detoxified alcohol dependent subjects and controls. During the instrumental training, participants learned that actions led to monetary rewards or to losses. During the pavlovian phase, subjects learned to pair monetary rewards or losses with pictures of drinks (alcohol and water). Findings from the transfer phase, showed that patients had a stronger suppression of instrumental actions when the CS associated with monetary losses were presented at the screen, revealing that healthy controls and detoxified patients differed in “wanting” response for monetary losses.

**PIT, fragrances and flavours**

The PIT paradigm has been applied to the chemosensory field (Pool et al., 2014) by using a single sweet olfactory stimulus (chocolate) for individuals in stress and stress-free condition. During, the instrumental phase, participants learned to correctly squeeze a handgrip to trigger the release of chocolate reward. During the Pavlovian training, participants learned to associate neutral images with the presence or the absence of the chocolate odour. Before the transfer test, half of the participants were submitted to a socially evaluated cold pressor test to induce physiological stress. During the extinction phase of the transfer test, participants were instructed to perform the same task learned in the instrumental conditioning. Results showed that acute stress in human enhanced instrumental action to obtain the sweet olfactory stimulus during the extinction phase of the transfer test. With this study, the sensitivity to detect the “wanting” for a single olfactory reward has been validated.

2.3.8 Conclusion

In the above chapter, the PIT paradigm, the instrumental and Pavlovian factors influencing it and procedures used in the human literature were presented. PIT concept refers to the ability of a
Pavlovian stimulus (that predicts a reward) to enhance an instrumental action to obtain a reward. It exists three kinds of paradigms: the outcome selective, the no-selective and the full transfer paradigms. Brain regions have been highlighted in response to the transfer effect in animal and in human. In human, PIT test has mainly been used to assess the presence of specific and general transfer, action specificity, neuropsychiatric disorders and individuals’ differences. PIT designs were divided in analog to non-human or new “game-like” paradigms. Concerning the human PIT paradigm applied to fragrances, transfer effect was observed when one sweet olfactory reward was given. In this thesis, we investigated if PIT paradigm was sensitive enough to differentiate “wanting” for two olfactory rewards.

2.3.9 PIT paradigm used in this thesis
Consumer studies are interested to better understand the motivation behind rewarding products. The PIT paradigm seemed to be a promising method to measure “pure” wanting for a single sweet olfactory reward. The goal of this thesis was to assess the PIT sensitivity to measure effort mobilized to obtain a pleasant olfactory stimulus compared to a second pleasant olfactory one. Normally, the procedure used in the presence of multiple rewards is the outcome selective, where two stimuli (S1 and S2) are paired with two outcomes (O1 and O2) and two types of responses (R1 and R2) are used to obtain the same outcomes (O1 and O2) (see section 2.3.4).

In our experiment, we wanted to investigate the difference in the amount of effort mobilized to obtain one odour compared to a second odour instead of differentiating the motivation for two rewards only based on the type of button pressed on a keyboard. For this reason, we decided to measure the effort mobilized by means of the same instrumental tool: a hand grip allowing us to measure mobilized effort through the measurements of number of peak and the strain (chapter 3.2 for more details). With our experiments, we wanted to investigate the limit of our tool and procedure in the investigation of the effort’s difference between two olfactory rewards. We expected to find a sensitivity of the PIT paradigm to show a transfer effect for the mostly pleasant stimuli compared to mildly pleasant one and an amplified transfer effect for relevant olfactory rewards according to the modified physiological state and personal need.

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<th>Pavlovian Conditioning</th>
<th>Instrumental Training</th>
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<tr>
<td>CS1 → O1</td>
<td>Intensity and peaks number of R → O1 or O2</td>
<td>CS1: R? ≠ CS2: R?</td>
</tr>
<tr>
<td>CS2 → O2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CS0 → no O</td>
<td></td>
<td>CS0: R?</td>
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PIT paradigm: Pavlovian Conditioning → Instrumental Training → Transfer Test.
2.4 Stimuli used in the thesis to elicit “wanting”

The following section will describe the stimuli used in this project. In investigating the sensitivity of the PIT paradigm, we decided to use pleasant olfactory stimuli as unconditioned stimuli. Odours are ideally stimuli for influencing « wanting » component of the reward process, because they might rely more on implicit processes than visual or auditory stimuli (Köster, 2005). All reported studies employed olfactory stimuli.

In the following chapter, the four dimensions of odours and the functions of olfaction will be presented.

2.4.1 Odour definition & descriptors: familiarity, intensity, hedonicity

Odour is a “sensation resulting from the interaction of volatile chemical species inhaled through the nose, making contact with the olfactory area and registering in the brain. Not all chemical compounds impinging on the olfactorium produce the odour sensation. Odour may be considered as having at least two parameters: quality and intensity” (Leonardos, Kendall, & Barnard, 1969, p.92).

In addition to these two parameters, odours are often assessed through the subjective experience along two supplementary perceptual dimensions such as familiarity and edibility. In total, four dimensions are normally assessed: hedonicity (pleasantness, valence or quality), intensity, familiarity, and edibility. The pungency is also accessed when the olfactory stimuli activated both the trigeminal and olfactory system (Cometto-Muniz & Cain, 1994). Hedonicity is the term used to describe the hedonic quality (pleasant/unpleasant, or positive /negative) of the emotion elicited by a given stimulus by means of self-report (Brosch & Moors, 2009). Hedonicity is considered as the most important dimension (Yeshurun & Sobel, 2010a), because it is the dominant dimension in odour perception (Richardson & Zucco, 1989) and may allow one to differentiate between multiple olfactory stimuli (Yeshurun & Sobel, 2010b). According to Gendolla & Brinkmann (2009), pleasant stimuli can become rewarding if they constitute the desirable outcome of a behaviour. An animal/individual tends to more easily approach a new pleasant odour compared to an unpleasant odour. The evaluation of hedonicity (as the other dimensions) can vary in a single person according to her physiological state (e.g. hungry satiety, ill, menstrual cycles), between different individuals, and across cultures. For instance, a given food eaten to satiety will decrease the pleasantness level of the food and of the food-odour related because the need for calories of that specific food is no longer necessary (Small, Zatorre, Dagher, Evans, & Jones-Gotman, 2001). In addition, hedonic value of an odour can be influenced by the presence of a more pleasant or unpleasant odour (Mohanty & Gottfried, 2013) or by other contextual cues (such as verbal, sematic or sensory) (Gilbert, Martin, & Kemp, 1996; Zellner & Kautz, 1990).
The second important dimension is intensity defined as strength of an observed odour in the environment. Perceived odour intensity is the relative strength of the odour above the recognition threshold (Leonardos, Kendall, & Barnard, 1969). Intensity plays a major role in the detection of an odourant (Doty, 1975), and can be influenced by contextual cues such as the color hues (Gilbert, Martin, & Kemp, 1996; Zellner & Kautz, 1990). After a period of exposure to an odorant, the perceived intensity decreases. This mechanism is defined as olfactory habituation and is an adaptation at the central level to facilitate the detection of novel odours against a longer standing, non-relevant olfactory background (Kadohisa & Wilson, 2006; Stevenson & Wilson, 2007).

Intensity and hedonicity are not directly correlated but are mainly bonded by other correlations according to the type of odour (Bensafi, Rouby, Farget, Bertrand, et al. 2002 a, b; Distel et al., 1999; Doty, 1975). According to Bensafi et al. (2002), intensity is considered a proxy of arousal. Arousal is defined as « a condition conceived to vary in a continuum from a low point in sleep to a high point in extreme effort or intense excitement» (Duffy, 1962, p. 5). However, low arousal emotions (such as sadness) can be experienced intensively and in this case, perceived intensity of an emotional response is different compared to the arousal of an emotion. Intensity of an odour is influenced by internal and external factors such as affective states (Kobayashi et al. 2008), humidity, temperature (Mainland & Sobel, 2006), or molecular concentration of odorant molecules available in the surrounding environment. In addition, research showed a positive correlation between intensity and familiarity, indicating that when intensity increases, familiarity increases proportionally (Distel et al., 1999) and that intensity is also higher rated if the source of odour is known (Distel & Hudson, 2001).

Familiarity indicates the degree at which a person has already smelled a specific odour or not. Familiar odours are easier to discriminate and remember (Lehrner, Walla, Laska & Deecke, 1999; Degel et al, 2001) because their consequences are already known. Familiarity reflects learning, experience, and meaningfulness (Livermore & Laing, 1996).

Hedonicity and familiarity are often correlated: familiar odours are generally perceived as more pleasant compared to unfamiliar odours (Distel & Hudson, 2001; Herz, 2005; Sulmont, Issanchou, & Koester, 2002) partially due to the exposure effect (Zajonc, 1968). Familiar odours have already been appraised by novelty stimulus check (Sander, Grandjean, & Scherer, 2005) and consequently the positive or negative consequences of being in contact with them are known by the animal/individual (Gottfried & Wu, 2009). This correlation is mainly present for pleasant odours compared to unpleasant odours (Delplanque et al., 2008). If the source of the odour is known, the familiarity is rated higher (Distel et Hudson, 2001). Subjective qualities of an odour are defined by using hedonicity, familiarity, and intensity dimensions.
2.4.2 The functions of olfaction

The odour dimensions are not independent, and they embody the olfactory functions (Doty, 1975; Stevenson, 2010). The dimensions presented above are at the basis of the induction of adaptive behaviours for survival (Pause et al., 2003), of the concept of salience/relevance of an odour, and of the approach or avoid action tendencies (Frijda, 1987).

Stevenson (2010) defined four functions of human olfaction that are classified according to the behavioural adaptations to changes in environment for survival: ingestion, hazard avoidance, social communication, and emotional contagion. An odour is relevant if it significantly increases or decreases the attainment of the individual goals, needs, and well-being (Sander et al., 2003). According to Stevenson (2010), survival depends on the capacity of the olfactory system to detect and identify putative nutrients and to avoid microbial contamination or poison. Orthonasally detected odours can help in distal location of food but also at a proximal level to identify a food's suitability for ingestion. When the food is in the mouth, volatiles that are released during chewing or swallowing stimulate olfactory receptors via the nasopharynx-retronasal olfaction system. This system assists in the choice of further consumption of a specific food or rejection of it when the perceived flavor is different compared to the expected flavor before ingestion. In neonates, nasopharynx-retronasal olfaction system helps in initiating and maintaining breast-feeding. Finally, Stevenson argued the necessity of odours to regulate food intake by stimulating appetite before, during or after meal consumption and develop the sense of satiety.

The second survival function of olfaction is the identification and avoidance of environmental hazards. Volatile chemicals can be a source of nonmicrobial (predators, poisons, fire) or microbial threats (feces, vomit, and organic decay), and develop fear and/or disgust (see experiment 4).

The social communication through odours has also been studied. The detection and exchange of chemosensory information between conspecifics is defined by Stevenson (2010) as one of the principal functions of olfaction. Social communication through odours is the dominant channel of communication in many invertebrates and less dominant in vertebrates. In humans, this function seems to be more developed in females than males in that females better identify chemosensory information in olfactory tasks. In social communication, two of the main sub-functions are the detection of genetic fitness in potential mates and the inbreeding (incest) avoidance. Olfactory cues provide general health information on a potential mate, and sick organisms frequently emit unpleasant odours that are often different from odours emitted by healthy individuals. Moreover, in human males, olfactory cues are signals of symmetricity (and better fitness characteristic) for females during their menstrual cycles (due to progesterone and oestrogen variations). According to Bateson's theory of optimal outbreeding (1983), a good potential mate is one that genetically differs from self, but not too much. Heterozygosity and avoidance of inbreeding is important to confer resistance to infectious
agents. The formation of other odour-profiles starts in neonates that have the ability to learn the odour signature of their mother. When a child is exposed to another child of opposite sex’s odours, he/she forms a memory that makes him/her less inclined to engage in a sexual relationship with that child in the future. However, inhibition and avoidance can be negatively modulated from someone’s culture in which early exposure does not influence future sexual relationships.

Finally, another important olfactory function is the ability to detect threats that emanate from another conspecific individual via the olfactory channel. For instance, females are consciously able to detect fear emotion from a sweat sample of a fearful donor. This mechanism helps to enhance vigilance. Moreover, neonates are able to detect their mother’s odour and the presence of the odour has calming effects. The calming effects of partners or family members of odours has also been found.

In this thesis, we decided to use odours for two reasons: first, they are easy to manipulate and second they are primary rewards having an innate value and biological significance (Gottfried, 2010). Moreover, to avoid any potential confound with the concept of expected pleasantness we decided to use olfactory stimuli that could be consumed during the experiment. The measure of liking was done immediately at the end of the task (after the extinction phase of the transfer test where we measured “wanting” component).
2.5 Objective of the thesis

In fragrance and flavour field, human PIT has only been used in presence of a single olfactory reward (Pool et al., 2014). We were interested in investigating whether PIT could measure “wanting” in presence of multiple olfactory rewards. The aim of this thesis was threefold: (a) testing PIT procedure in chemosensory context when two pleasant olfactory stimuli are simultaneously employed, (b) testing PIT procedure according to physiological state of participant in two different contexts, and (c) experimentally dissociating “wanting” from liking according to participants’ needs.

Four experiments were created to test PIT’s sensitivity. In a first experiment, we questioned whether the PIT could measure the “wanting” when two olfactory stimuli with different rewarding proprieties were presented (experiment 1). In a second experiment, we questioned sensitivity of PIT to measure “wanting” when two olfactory outcomes having similar reinforcing proprieties were used (experiment 2). Based on the results of these experiments, we further sought to understand the “wanting” component of the reward process by empirically testing factors amplifying reward’s salience. According to IST, physiological states (e. i. stress, hunger, tiredness) and personal need could positively or negatively influence the psychological components of the reward process (Kringelbach & Berridge, 2012). In experiment 3, we induced a physical disgust feeling in healthy individuals and tested their motivational response to obtain cosmetic related and food (no cosmetic) related olfactory stimuli with similar liking level.

In experiment 4, we manipulated hunger physiological state in healthy subjects by means of a satiation manipulation and tested effects on “wanting” to obtain food and cosmetic (no alimentary) olfactory rewards with different liking level.
3. EXPERIMENTAL PART
3.1 Methodology introduction
In the experimental part of the thesis, we presented the four experiments where PIT paradigm had been adapted to investigate our four main research questions, i.e. testing PIT procedure in chemosensory context when two pleasant olfactory stimuli are simultaneously employed; testing it according to physiological state of participant in two different contexts, and experimentally dissociating “wanting” from liking according to participants’ needs; exploratory investigate whether the concept of expected pleasantness and of “wanting” correlation.

The studies presentation followed a description of tool used to deliver odours and to measure effort (participants were willing to invest to obtain the rewards).

Delivery of odours
In all experiments reported here, an olfactometer (see Figure 2a) was used. The odours were smelled by participants through a cannula (see Figure 2b).

Figure 2a, b. a) Olfactometer used in the studies; b) Cannula used to deliver the odours directly in the nose of participants.

Operationalization of “wanting” component through an isometric dynamometer
“Wanting” was operationalized as the mobilized force used by the participants to obtain a reward. It was measured by means of a hand grip/ dynamometer.
The TDS121C isometric dynamometer connected to a MP150 Biopac Systems (Santa Barbara, CA) was used to calculate the energy investment of participants. Variation in compression of TDS121C isometric dynamometer resulted in a differential voltage signal that was linearly proportional to the force exerted by participant.

Experiment 1, 2, and 4 were performed at the behavioural laboratory of the University of Geneva and experiment 3 at Firmenich, S.A. The data was recorded on each trial (12s) at 30Hz (for experiment 1, 2, 4) and 60Hz (for experiment 3), giving a total of 360 samples (data points) in experiment 1, 2, 4 and 720 data points in experiment 3 per trial.

In our experiments, we measured the mobilized force by calculating the number of squeezes on a hand grip exceeding a criterion of 50% of participant’s maximal force (Talmi et al., 2008; Pool et al. 2014) and by calculating the total strain on the hand grip. In the following chapter, the pre-processing, post-processing, of these two indicators of “wanting” will be described.

3.1.1 Pre-processing

3.1.1.1 Standardization of the signal

The following procedure was applied to calculate the force from the squeezes performed on the hand grip by each participant. Each data point was recorded at every 33.33ms (for experiment 1, 2 and 4), and at every 16.66ms (for experiment 3). By means of Matlab, we performed a standardization as following: we subtracted the minimal voltage value to each data point and this value was divided by the difference between the maximum voltage minus the minimum voltage.
The equation for standardization was the following:

\[
Data\ point\_s = \frac{(Data\ point\_tp - V_{\min})}{(V_{\max} - V_{\min})}
\]

*Note. Data point\_s = standardised value without any unit; Data point\_tp = pression exerted by the subject at a specific moment in Volts; V\_min = minimal value of the participant’s exerted pression in Volts; V\_max = maximal value of the participant’s exerted pression in Volts.*

Following the standardization, the signal varied between 0 (as the minimal force) and 1 (as the maximal force) and did not have a unit anymore. This equation allowed us to compare data of the subjects between them.

### 3.1.1.2 Integration of the signal

After performing the normalization and the standardization, we integrated the signal by using the trapezoidal numerical integration of Matlab to compute the area of the signal and deriving the total force exerted in each trial. The results were expressed in standardized values (without unit) over a period of 12 seconds.

### 3.1.2 Post-processing

#### 3.1.2.1 Indicators of “wanting”

Two indicators have been used to measure “wanting”:

1. Number of squeezes on a hand grip
2. Total exerted force

In the following chapter, each indicator will be presented.

1) Number of squeezes on a hand grip

Based on Pool et al. (2014), this indicator took in to account only the number of squeezes on a hand grip exceeding a criterion of 50% of participant’s maximal force (Figure 3).
Figure 3. The y-axis represented the standardized force (that does not have a unit measure and varies between 0 and 1). The x-axis represented the time (in seconds and varies from 0 to 120 ms). In the above graph, participant exerted 2 peaks superior to the 50-70% of their maximal force during the presentation of olfactory reward during 12 seconds of presentation.

1) Total exerted force

By measuring the integral of the handgrip signal on the standardized values of each data point, we measured the total amount of force (area) exerted by the participants when the CS1, CS2, and the baseline were presented (Figure 4). The rationale behind the force measured was that we wanted to investigate in an exploratory way whether participants developed more effort with this indicator compared to peak parameter. In contrast to the peak measure, total exerted force reflected the energy investment during the whole 12 seconds of measurement. As illustrated in Figure 4 in the two ovals, the force exerted to perform a peak can be different from one peak to the other, from one participant to the other and one trial to the other. The total force on each block for each repetition and each Pavlovian stimulus was recorded, with a total of 18 trials for each participant.
Figure 4. The y-axis represented the force exerted by a participant for a potential stimulus shows at the desktop and x-axis illustrated the time. Area under the curve represented the integral of the handgrip signal. The total exerted force during a block for a specific stimulus (CS1, CS2 or baseline) corresponded to the sum of integral of the handgrip signals during that specific block. Total force exerted to perform one peak could change from one peak to the other or from one person to the other.
3.2 Handgrip calibration for the experiment

3.2.1 Hand Dynamometer Calibration

Maximum voluntary handgrip strength was measured with isometric handgrip. The TDS121C isometric dynamometer measures gripping (compression) or pulling (tension) forces associated with a wide variety of muscle groups, measure grip, arm curling, leg lifting, digit activation forces, etc. The dynamometer was calibrated with respect to the participant’s minimal and maximal strength exerted on the grip. The calibration was done prior to the instrumental and transfer phases of the PIT paradigm. Participants were sitting comfortably in a chair. The right position of the dominant hand on the hand grip was under the eyelets (see figure 5). The force was applied on a large surface corresponding to the whole hand of the subject. Participants then applied as much pressure as possible for at least 12 seconds. The elbow was at a 90 degrees angle, and it was without any supports.

Figure 5. During the calibration phase, the correct position of the dominant hand was under the two eyelets

The examiner demonstrated once how to correctly hold the handle to each participant before the calibration phase of the instrumental conditioning. Then he gave the dynamometer to the subject. After the subject was positioned appropriately, the examiner asked the participant if he was ready, and to squeeze as hard as he could. Minimal value was recorded when the participant held the hand grip (with his dominant hand) without performing any pression on a period of 7s. Maximal value was recorded when the individual pressed with his maximal force on the dynamometer with his dominant hand on a period of 7s.
CHAPTER 3

EXPERIMENTAL PART

EXPERIMENTS

In the following section the four experiments performed to answer to our objectives were presented.

3.3 EXPERIMENT 1 & 2

Investigating the sensitivity of the PIT paradigm to measure “wanting” of rewarding olfactory stimuli different in consummatory pleasure

Abstract

The incentive salience theory suggests that the pursuit of a positive outcome (reward) is influenced by the motivation to obtain it (wanting), the pleasure felt during its consumption (liking), and its automatic associations and cognitive representations (learning). These components have widely been studied in rodents but not in humans. A promising paradigm used to investigate “wanting” in animals and humans is Pavlovian-to-instrumental transfer (PIT). This paradigm allows “wanting” to be specifically measured in the absence of the liking component. The human PIT has been used in the chemosensory field in the presence of a single olfactory reward (chocolate odour). In the present methodological study, we measured cue-triggered “wanting” for one olfactory reward compared with that for a second olfactory reward. Specifically, we tested the sensitivity of the PIT task in two studies. The first used two olfactory stimuli with very different liking levels, whereas the second used two olfactory stimuli with only slightly different liking levels. Two indicators were used to operationalize “wanting”: the number of peaks exceeding 50% of the maximal force of the participant and the total force exerted by the participant. Results suggested that the PIT task was sensitive for detecting the effort mobilized (“wanting”) to obtain two olfactory stimuli with very different liking levels. This task did not, however, differentiate “wanting” between olfactory stimuli with slightly different liking levels. These findings provide useful information concerning the ability of the PIT task to measure the effort mobilized to obtain olfactory stimuli differing in liking levels.
3.3.1 Introduction

Although the response to a reward varies from one individual to another, each organism typically wants to experience positive stimulations such as rewards and to avoid negative stimulations such as punishments. A well-established framework of reward processing, the incentive salience theory (IST), argues that the pursuit of an outcome is not always directly proportional to the pleasure delivered during its consumption, but is also influenced by the effort an organism is willing to invest to obtain said outcome. Pioneers of the theory Robinson and Berridge (1993) argued that the pursuit of a positive outcome (a reward) is influenced by the pleasure felt during its consumption (liking), the motivation to obtain it (wanting), and its automatic associations and cognitive representations (learning). The definition of these components evolved over the years on the basis of empiric evidence. In 2010, each of these components was defined with and without quotation marks (Berridge, 2010). Wanting, liking, and learning (without quotation marks) referred to the common meaning of the terms motivation, pleasure, and cognitive learning, respectively. “Wanting,” “liking,” and “learning” (with quotation marks) referred to their meaning in the IST context. Thus, “wanting” was the motivational attractiveness of a stimulus (incentive salience) that does not always require consciousness and leads “animals and humans to approach and work to obtain the reward” (Anselme & Robinson, 2016, p. 124). “Liking” referred to a hedonic reaction that was not accompanied by conscious pleasure. Finally, “learning” referred to the Pavlovian and instrumental learning associations from past hedonic experiences (Anselme & Robinson, 2016, Berridge, 1996, Kringelbach, & Berridge, 2011). On the basis of rodent studies (Wyvell & Berridge, 2000), the IST proposes that the “liking” component can be measured independently from the “wanting” component. According to Berridge (2009a, 2009b), the “liking” component could be measured by using orofacial expressions and the “wanting” component by measuring the effort mobilized to obtain a reward. Typically, the three components involved in reward processing are positively correlated (e.g., you “want” what you “like” and you “learned” it from previous experiences), but they can also be dissociated, such as in addiction, with the consequence that an individual may feel excessive motivation to obtain a reward but decreased enjoyment when it is obtained (Robinson, Fischer, Ahuja, Lesser, & Maniates, 2016; Robinson & Berridge, 1993). Whether these components can be dissociated in humans is still highly debated, as several methodological issues render it difficult to extend this animal model to human research.
(for a review, see Pool, Sennwald, Delplanque, Brosch, & Sander, 2016). The fact that humans are able to fake facial expressions and inhibit consummatory impulses (Tibboel et al., 2011) represents one such methodological difficulty in measuring liking with a similar method as that used in rodents. However, a report of liking and a measure of “wanting” in humans showed that, under stress, “wanting” and liking can be dissociated, with an individual working hard to obtain a reward that is no longer necessarily liked (Pool, Brosch, Delplanque, & Sander, 2015; see also Sennwald, Pool, & Sander, 2017).

There are two major challenges in measuring “liking” and “wanting” in humans: (1) the development of methods allowing the study of the psychological components of reward processing in the correct unfolding order and (2) the development of methods operationalizing the definitions of different forms of liking and wanting correctly, especially the operationalization of “liking” and “wanting” shared by non-human animals (for a discussion, see Pool et al., 2016). Concerning the first challenge, Kringelbach and colleagues (2012) showed that reward processing goes through a cyclical time course: it starts with a wanting phase (which may parallel the expectation of reward), which leads to a liking phase (consumption of the reward) that can have a peak level of pleasure (e.g., a tasty meal, sexual orgasm, a drug rush), and finishes with a learning phase (where the organism learns and updates predictions for the reward). These components should be measured at the right moment in the cyclical time course. If they are not, psychological processes other than motivation, the reward’s hedonic impact, and the learning mechanism might be measured instead. According to IST, the best moment to measure the reward’s hedonic impact (hedonic reaction and/or cognitive pleasure) is during or immediately after reward consumption. If the impact is measured too long after reward consumption, it is unclear whether, rather than liking, the encoded memory of the pleasurable experience is being measured. The best moment to measure incentive salience is during the instrumental action to obtain the incentive cue (reward-associated cue), which is presented before the instrumental performance. During the instrumental task, the incentive cue must be presented before the instrumental action; otherwise, reinforcement learning would instead be measured. In fact, to measure “wanting”, it is important that an individual learns the contingency between the instrumental action and the reward.

The second challenge concerns the methods that should be developed to operationalize these two concepts in humans. Measuring “wanting” and “liking” seems to be more difficult than measuring the explicit facets of these components. The main reason is that these two components are not
explicitly experienced and, consequently, they cannot be investigated by using explicit measures (Tibboel et al., 2011; Tibboel, De Houwer, & Van Bockstaele, 2015). The findings on the assessment of “liking” and “wanting” are currently ambiguous; this is mainly due to the incorrect operationalization and interpretations of the implicit components as defined by the IST (Pool et al., 2016).

Another difficulty in operationalizing these concepts arises because their definitions have changed over the years. Indeed, Berridge and colleagues (1995, 1998, 2003, 2008, 2010, 2014) published several articles in which the theoretical definitions of the components seem to have evolved. These modifications were based on empirical research of more than 30 years; although it has increased our knowledge of reward processing, it has also increased confusion on how to best define these concepts. In several studies, researchers claimed to test components of the reward system, but in fact, they measured the expectations of how pleasant or not pleasant something was going to be. This confusion is mainly due to the concept of expected pleasantness being sometimes operationalized to reflect “liking” and sometimes to reflect “wanting”. However, expected pleasantness encompasses the predictions and expectations of how pleasant or not pleasant something is going to be (Berridge & Aldridge, 2008) and does not correspond to the “wanting” and “liking” components (Pool et al., 2016).

Methods used to measure the implicit components

Currently, “liking” is mainly assessed by examining brain activity in the hedonic hotspots when an organism consumes a reward or by measuring hedonic reactions from the individual’s emotional facial expressions (Berridge, 2000; Berridge & Kringelbach, 2008; Smith, Mahler, Peciña, & Berridge, 2010; Steiner, 1973). In addition, heart rate and rectal pressure variability are other “liking” indicators in humans, especially for sexual “liking” (Thomsen et al., 2015). “Wanting” is measured through conditioned approaches, incentive key press/force grip tasks, and effort expenditure for reward tasks. Moreover, scientists have developed additional methods to precisely measure “wanting” and “liking” in humans.

From the IST’s assumption that “wanting” and “liking” are automatic processes (Kringelbach & Berridge, 2010a, b), one potential way to assess them is by using implicit measures (Tibboel et al., 2011; Tibboel et al., 2015). The main advantage of implicit measures is that they might capture mechanisms that are not introspectively accessible. Consequently, they are less consciously
controlled and less susceptible to extraneous factors (social desirability, deception). Accordingly, several implicit measures have been adapted to investigate these two implicit components, including the Stimulus Response Compatibility Test (De Houwer, 2003), the Affective Simon Task (De Houwer & Eelen, 1998), the Approach/Avoidance Task (Rinck & Becker, 2007), and the Implicit Association Test (Greenwald, McGhee, & Schwartz, 1998).

Concerning “wanting”, a promising method is the Pavlovian-to-instrumental transfer (PIT) task, which has largely been used in animal studies (Wyvell & Berridge, 2000) and in the last decade, adapted for human research as well. This paradigm allows a “pure” measure of the effort participants mobilize to obtain a reward (“wanting”) without explicitly asking them about their cognitive desires. The task is divided into three phases: instrumental, Pavlovian, and transfer test. The instrumental phase consists of instrumental conditioning, in which the individual learns that performing an action can lead to a reward. In Pavlovian conditioning, the subject learns to associate a neutral stimulus with the absence or presence of a reward, which is referred to as the unconditioned stimulus. If a neutral stimulus is associated with a reward, it becomes a reinforced conditioned stimulus (CS+); if no reward is associated with a neutral stimulus, it becomes the non-reinforced conditioned stimulus (CS-). In the transfer test (test phase), the influence of the Pavlovian stimuli (CS+ and CS-) on instrumental action is measured (transfer effect). The transfer test is usually performed under extinction in order to avoid any primary reinforcement caused by the presence of the reward. If the PIT effect takes place, the CS+ presentation induces an increase in action energization after its presentation. At the end of the experiment, this measure is taken to reflect cue-induced “wanting”. There are multiple particularities to this task. For instance, it is a paradigm measuring “wanting” by means of conditioning tasks. Moreover, “wanting” is measured outside and after the consummatory phase, giving researchers the opportunity to assess “wanting” independently of the presence of the reward, thereby avoiding confusion with the reinforced learning concept.

The PIT paradigm has been applied to the chemosensory field (Pool et al., 2015) by using a single sweet olfactory stimulus (chocolate) for individuals in a stressful and stress-free condition. During the instrumental phase, participants learned to correctly squeeze a handgrip to trigger the release of the chocolate reward. During Pavlovian training, participants learned to associate neutral images with the presence or absence of the chocolate odour. Before the transfer test, half of the participants underwent a socially evaluated cold pressor test to induce physiological stress. During the
extinction phase of the transfer test, participants were instructed to perform the same task learned in instrumental conditioning. Results showed that acute stress in humans enhanced instrumental action to obtain the rewarding olfactory stimulus during the extinction phase of the transfer test. This study validated the sensitivity of detecting “wanting” for a single olfactory reward. However, to our knowledge, no study has yet adapted the PIT paradigm in humans to compare multiple olfactory rewards.

Objectives
In the current study, we investigated the sensitivity of the PIT task by comparing cue-triggered “wanting” for two olfactory rewards. In this series of experiments, effort mobilization was assessed with two indicators: (1) the number of peaks exceeding a criterion of 50% of the participant’s maximal force and (2) the total force exerted by the participant when presented with the cue. In addition to this first objective, and on the basis of the literature, we investigated the potential relationship between expected pleasantness (i.e., how pleasant or unpleasant something is going to be in the future) and “wanting” (see Pool et al., 2016). We conducted two experiments to investigate the sensitivity of the PIT task. More specifically, we aimed to differentiate cue-triggered “wanting” for one olfactory reward from “wanting” for a second olfactory reward. In the first experiment, we used stimuli with markedly different rewarding properties (measured as the liking level). We posited that the sensitivity of the PIT task would be reflected by greater “wanting” for images associated with highly rewarding odours (CS1) compared with that for images associated with mildly rewarding odours (CS2). In the second experiment, the limits of the sensitivity of the measurement were tested: we used stimuli that slightly differed in their rewarding properties (measured as the liking level). Our prediction was that if the PIT task was a sensitive measure, it could differentiate “wanting” for olfactory stimuli that slightly vary in their liking levels.

In addition to this first objective, we explored whether “wanting” correlates with expected pleasantness. We measured expected pleasantness by means of the Temporal Experience of Pleasure Scale (TEPS; Gard, Gard, Kring, & John, 2006), in which an individual’s trait disposition related to imagery of a potential pleasurable event was measured; we correlated this score with the “wanting” score. We assumed that if the two constructs were correlated, individuals having a higher score for expected pleasantness would mobilize more effort in the PIT test.
Finally, effort mobilization was assessed with two indicators. In addition to measuring the number of peaks, we also used another indicator of “wanting”: the total force produced by the participant. Specifically, by measuring the integral of the handgrip signal on the standardized values of each data point, we were able to calculate the total amount of force (area) exerted by the participants when CS1, CS2, and the baseline were presented on the screen. In contrast to the peak measure, the total exerted force reflected energy investment during an interval of time.

3.3.2 Experiment 1

Goal
The aim of this experiment was twofold: (1) to investigate whether the PIT procedure was a sensitive tool to differentiate “wanting” between olfactory stimuli that highly differed in liking levels and (2) to explore whether “wanting” correlated with expected pleasantness. To answer our questions, we adapted an analogue of a human PIT that originally used one olfactory reward (i.e., chocolate odour; see Pool et al., 2015) to two odours with different liking levels. We expected higher motivation for obtaining the olfactory stimuli with a higher liking level. In addition, we explored whether “wanting” correlated with expected pleasantness. We hypothesized that if the two concepts were correlated, individuals mobilizing more effort during the transfer test would have a higher score for expected pleasantness during questionnaire assessment.

3.3.2.1 Method and Materials

Participants. Sixty-one undergraduate psychology students (10 men) participated for course credits. The study was approved by the FPSE ethical committee of the University of Geneva. The participants had no history of psychiatric or neurological diseases. They had normal or corrected-to-normal vision, no reported olfactory problems, and no smoking habits. They were between 20 and 46 years old (\(M_{age} = 21.7, \ SD_{age} = 4.10\)). Sixteen participants were later excluded on the basis of experimental criteria (see Results section). The study was performed in French and English.

Visual stimuli. We selected four abstract figures from an initial set of 33 figures that were evaluated as neutral by 34 participants (\(M = 27.7, \ SD = 2.97\)) on a 9-point Likert pleasantness scale from 0 (“not pleasant”) to 9 (“extremely pleasant”). Three images were used in the Pavlovian and transfer phases, one in the instrumental phase (Figure 6).
Figure 6. The four abstract images used during the experiment. The first image was used during the instrumental training, reminder and partial extinction of the transfer test. The second, third and fourth images during the Pavlovian and transfer test.

Olfactory stimuli. We selected nine odours from an initial set of 25 odours that were evaluated by 30 participants \((M = 28.6, \ SD = 5.66)\) for pleasantness, intensity, familiarity and edibility on a 10-point Likert scale from 0 (“not pleasant/not intense/not familiar/not edible at all”) to 10 (“extremely pleasant/intense/familiar/edible”) (Table 1). We created two groups of odours differing in pleasantness score: four pleasant odours having a liking score of around 50 points and five more pleasant odours having a liking score above 70 points on a pleasantness score of 100 points.

Table 1
The odours used for the study

<table>
<thead>
<tr>
<th>Odorant</th>
<th>Concentration (ml/l)</th>
<th>Dipropyleneol (ml/l)</th>
<th>Mean Pleasantness (SD)</th>
<th>Mean Intensity (SD)</th>
<th>Mean Familiarity (SD)</th>
<th>Mean Edibility (SD)</th>
<th>Category</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peach NP</td>
<td>5</td>
<td>5</td>
<td>7.32 (±2.47)</td>
<td>6.59 (±1.91)</td>
<td>5.93 (±2.60)</td>
<td>4.07 (±2.55)</td>
<td>Food</td>
</tr>
<tr>
<td>Linalol</td>
<td>5</td>
<td>5</td>
<td>7.01 (±2.28)</td>
<td>5.80 (±1.98)</td>
<td>4.93 (±2.79)</td>
<td>2.07 (±1.27)</td>
<td>Cosmetic</td>
</tr>
<tr>
<td>Tutti Frutti</td>
<td>2</td>
<td>8</td>
<td>8.36 (±2.13)</td>
<td>6.49 (±1.59)</td>
<td>8.40 (±1.59)</td>
<td>6.93 (±2.37)</td>
<td>Food</td>
</tr>
<tr>
<td>Geraniol</td>
<td>5</td>
<td>5</td>
<td>4.79 (±2.10)</td>
<td>5.58 (±2.52)</td>
<td>5.80 (±2.96)</td>
<td>2.93 (±2.49)</td>
<td>Cosmetic</td>
</tr>
<tr>
<td>Galbex</td>
<td>5</td>
<td>5</td>
<td>4.92 (±2.93)</td>
<td>6.29 (±2.22)</td>
<td>6.46 (±2.90)</td>
<td>4.13 (±3.39)</td>
<td>Cosmetic</td>
</tr>
</tbody>
</table>
Note. The essences were provided by Firmenich, S.A., Geneva, Switzerland. The essences were dissolved in propylene glycol.

**Instrumental apparatus.** An isometric handgrip dynamometer (TSD121C) was used to measure the effort that the individual mobilized (“wanting”) to obtain the different stimuli. The dynamometer was connected to a data acquisition system (MP150, Biopac Systems, Santa Barbara, CA) and recorded (sampling rate 30 Hz) with MATLAB (version 8.0). The participants received visual online feedback concerning the force they exerted on the handgrip (Psychtoolbox 3.0). This feedback consisted of an image of a thermometer displayed on the left side of the screen (30° visual angle). The “mercury” of this thermometer-like image moved up and down according to the mobilized effort exerted by the participant. The “mercury” reached the top of the scale if the handgrip was squeezed with at least 50% or 70% of the participant’s maximal force (randomly chosen for each data point for strength).

**Questionnaire.** Two versions of the TEPS were used: one in English (Gard et al., 2006) and one in French (Favrod, Ernst, Giuliani, & Bonsack, 2009) according to the language of the participant. This scale allowed us to evaluate individual traits in anticipatory and consummatory experiences of pleasure. The TEPS included two 6-point Likert scales from 1 (“very false for me”) to 6 (“very true for me”), measuring distinct constructs: the anticipatory and the consummatory scale. Specifically, the first scale was related to reward responsiveness and imagery and the second to openness to different experiences and appreciation of positive stimuli.
Procedure
The experiment was divided in two main phases: an odour evaluation and a PIT testing phase (divided in 3 sub-phases: instrumental, Pavlovian and transfer phases) (Table 2).

Table 2
The experimental design of the first experiment

<table>
<thead>
<tr>
<th>Instructions</th>
<th>Questionnaire</th>
<th>Odour evaluation</th>
<th>Instrumental</th>
<th>Pavlovian</th>
<th>PIT</th>
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</thead>
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<tr>
<td>Participation agreement, demographic</td>
<td>TEPS questionnaire</td>
<td>VAS evaluation of</td>
<td>Instrumental</td>
<td>Pavlovian</td>
<td>Transfer</td>
</tr>
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<td>10 odours</td>
<td>training</td>
<td>conditioning</td>
<td>test (18</td>
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<td>Selection of the</td>
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<td>trials)</td>
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<td></td>
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<td>mostly and the</td>
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<td>mildly rewarding</td>
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<td></td>
<td></td>
<td>odours</td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

7 minutes  5 minutes  5 minutes  12 minutes  16 minutes  15 minutes

Note. First participants filled in the consent form, the questionnaire on demographic information and the TEPS questionnaire. Second, participants performed an odour evaluation test on a computer screen. Two odours (mostly and mildly rewarding odours) were selected and used to perform the PIT test. These odours changed each time for each participant according to subjective preferences of the nine odours. The PIT task started with an instrumental conditioning training followed by a Pavlovian conditioning. Finally, individuals performed the transfer test. The total duration of the experiment was around 60 minutes. In the figure, the time is given for each part of the experiment.

Odour evaluation task. Before beginning the experiment, participants completed a consent form, a questionnaire on demographic information, and the TEPS questionnaire. On a visual analogue scale (VAS), each participant then evaluated the pleasantness, intensity and familiarity from 0 (“extremely unpleasant/ not perceived/ not familiar”) to 100 (“extremely pleasant/ extremely strong/ extremely familiar”) of 10 odours (one being propylene glycol as the control condition). We presented each odour once for 2 s by using a computer-controlled olfactometer (airflow 1 L/min) that delivered the olfactory stimulations rapidly, without thermal and tactile confounds, via a nasal cannula (Ischer et al., 2014; Pool et al., 2015). The mildly rewarding odour (close to 50 points on a 100-point VAS) was chosen for each subject. The odour receiving the higher score was selected as the mostly rewarding odour (from 70 to 100 points on the VAS). An additional selection
was done on the intensity level in order to select rewarding odours with similar levels of intensity on an individual basis. We accepted only those odours with an intensity score higher than 40 points on the VAS in order to avoid weak odours and to ensure that participants smelled the odours.

**Instrumental conditioning.** During this phase, participants learned to squeeze the handgrip to trigger the systematic release of one of the two odours (random order). We applied the procedure as previously described in Pool et al., (2015). Each of the 24 trials consisted of a 12 s “task-on” period and a 4 to 12 s (8 s average) “task-off” period. During the task-on periods, a neutral abstract image and a thermometer were presented in the centre and on the left side of the screen, respectively (Figure 7). Participants received visual online feedback concerning the force they exerted on the handgrip through the movements of the mercury in the thermometer. Participants were asked to keep their attention on the abstract image and to squeeze the handgrip correctly by bringing the mercury of the thermometer up to the maximum and then down again. In addition, they were told that if they happened to squeeze the grip during three special 1 s windows, they would receive the reward (odour). In reality, only two special 1 s windows were presented. They were free to choose when to squeeze and encouraged to use their intuition. During the task-off periods, the participants were told that they could have a break. During this period, a fixation cross was presented at the centre of the screen.
Figure 7. Instrumental conditioning. During the instrumental conditioning, participants learned to squeeze a handgrip to trigger the release of an odour. Fifty percent of the time the odour released was the mostly rewarding odour and fifty percent of the time was the mildly rewarding odour.

**Analog of Pavlovian conditioning.** In this task, neutral images were presented together with the odours. Participants were asked to mentally associate the images presented with the olfactory stimuli even if they were not able to identify the odour names. In our design, the neutral image presented with the mostly rewarding odour became the most positive conditioned stimulus (CS1) and the other image associated with the mildly rewarding odour became the other conditioned stimulus (CS2). A neutral image (presented without any odour) was used as the baseline. The association between a particular neutral image and an odour changed randomly across participants. There were 36 trials composed of a 12 s task-on period, followed by a 12 s task-off period. The task-on periods were as follows: a CS image appeared for 12 s at the centre of the screen during which a target (cross) was presented 3 times for a maximum of 1 s (Figure 8). Each time the CS1 and the CS2 image were displayed, the most rewarding odour and the mildly rewarding odour were released, respectively. During the task, participants were asked to press the “A” key on the keyboard as fast as possible as soon as they perceived the cross. The key-pressing task was only a measure of their sustained attention, independent of the Pavlovian task (Pool et al., 2015; Talmi et al., 2008). We told the subjects that the kind of odour
released depended only on the CS image and not on their performance during the key-pressing task. However, the odours were released faster when participants pressed the A key than when they did not in order to facilitate the action conditioning. In fact, according to that part, our phase was called analog Pavlovian conditioning and not a pure Pavlovian conditioning phase. The task-off periods were as follows: a baseline image was shown on the screen without any target and no odour was released. At the end of the conditioning procedure, participants evaluated the pleasantness of the images used (CS1, CS2, and baseline) on the VAS from 0 (“not pleasant at all”) to 100 (“extremely pleasant”). The images were presented randomly after the conditioning phase at the centre of the computer screen. Successful Pavlovian contingency learning was revealed by the likability of the CSs and the reaction time (RT; time to press the A key when the participants saw the Pavlovian stimuli for the first time).

**Figure 8.** Analog of Pavlovian conditioning. During the analog of Pavlovian conditioning, participants were exposed to repeat pairings of the most positive conditioned stimulus (CS1) associated to the mostly rewarding odour and the less positive conditioned stimulus (CS2) associated to the mildly rewarding odour. When the CS1 or CS2 were presented on the screen, a cross appeared in the centre of the picture and
participants had to press a key to trigger faster the release of the odour. When the baseline was displayed at the screen, no target or odour appeared.

**Transfer test.** Twelve trials identical to those in the instrumental conditioning phase (two special 1 s windows rewarded) were first administered followed by 12 trials administered under partial extinction (one special 1 s window rewarded). Eighteen transfer test trials were then administered under extinction (no time window rewarded). In this phase of the experiment, participants were requested to press the handgrip to obtain an olfactory reward, as in the instrumental test, while the abstract images conditioned during the Pavlovian phase were presented (Figure 9). With this procedure, we tested the effect of the Pavlovian conditioned stimuli on instrumental responding (PIT effect). The presentation order of the three stimuli was randomized in the transfer test. There were two cycles of testing: in each cycle, each cue was presented 3 times consecutively, so that each Pavlovian stimulus was presented 2 times for a total of 18 transfer trials.

**Figure 9.** Transfer test. Before the extinction phase, the subject performed a reminder and a partial extinction task. During the whole transfer test, the subjects were told to squeeze the handgrip if they wished to do so as learned in the instrumental conditioning training. CS1 corresponded to the abstract image
previously associated with the mostly rewarding odour, CS2 with the mildly rewarding odour and baseline was the abstract image without any odour association. CS1, CS2 and baseline were randomly presented.

3.3.2.2 Results
Participants were included in the study if (1) the pleasantness score of the mostly rewarding odour was greater than or equal to 70, (2) the mildly rewarding odour was different from the control odour (we excluded participants who chose the control odour as the second odour), (3) the difference in intensity between the most pleasant and the mildly rewarding odour was less than 20 (from the pre-tests, we wanted to avoid a pleasantness rating that depended on the intensity level), and (4) the intensity scores of the odours were greater than 40 (from the pre-tests, we considered an odour to be perceived if its intensity score was greater than 40).

In total, 16 subjects were excluded: four for the first criteria, four for the second criteria, three for the third criteria, and four for the fourth criteria. In addition, four subjects were excluded for technical problems with the handgrip recording, leaving 45 subjects for the statistical analysis.

Odour evaluation
Paired t tests revealed that mean pleasantness rating of the mostly rewarding odours ($M = 85.10$, $SD = 7.80$) was statistically higher than of the mildly rewarding odour ($M = 52.11$, $SD = 3.7$), $[t(44) = 25.31, p \leq .001, d = 5.41]$ (Figure 10a). The mean intensity of the mostly rewarding odours ($M = 72.58$, $SD = 10.73$) was statistically higher than of the mildly rewarding odour ($M = 61.12$, $SD = 15.60$), $[t(44) = 4.78, p \leq .001, d = .84]$ (Figure 10b).
**Figure 10a.** Distribution of the pleasantness score for the mostly rewarding odours and the mildly rewarding odours ($N = 45$). The y-axis illustrated the pleasantness scores at the VAS scale. The x-axis showed the type of odour (mostly and mildly rewarding odours). Error bars represented SEM. *** $p \leq .001$.

**Figure 10b.** Distribution of the intensity scores for the mildly rewarding odour and the mostly rewarding odour ($N = 45$). The y-axis illustrated the intensity score at the VAS scale. The x-axis showed the type of odour (mostly and mildly rewarding odours). Error bars represented SEM. *** $p \leq .001$.

**Instrumental conditioning**

A repeated-measures analysis of variance (ANOVA) applied to the number of squeezes exceeding 50% of each participant’s maximal force over 24 trials did not show a significant effect of trial
[\( F(23, 1012) = 0.72, p = .83, \eta^2 = .016 \)] suggesting that from the beginning of the task, participants pressed sufficiently and constantly to perform the task after a short training phase (Figure 11).

Figure 11. Instrumental conditioning. Y-axis represented the number of squeezes and the x-axis the number of trials over time.

**Analog of Pavlovian conditioning**

Successful Pavlovian contingency learning was revealed by the reaction time (RTs) of the key-pressing task (Figure 12a) and by likability rating of the CSs (Figure 12b) indicators.

**Reaction time (RT) indicator**

For the key-pressing task, we analysed RTs on the first target of the task-on period (Figure 12a). The results showed that during the first trial, the CS1 \((M = 408.28, SD = 56.22)\) didn’t produced significantly smaller RTs among participants compared to the CS2 \((M = 401.95, SD = 72.38)\), \([t(44)] = 0.75, p = .46, d = 0.10\).
Figure 12a. The analog of Pavlovian conditioning. The y-axis illustrated the reaction time (ms) to detect the cue during the presentation of mostly positive conditioned stimulus (CS1) and of mildly positive conditioned stimulus (CS2). The x-axis illustrated the type of Pavlovian stimuli (CS1 and CS2). Error bars represented SEM.

**Likability rating indicator**

A repeated-measures analysis of variance (ANOVA) applied to the likability ratings of the three Pavlovian images (CS1, CS2, baseline) revealed a significant effect of image, \[ F(2, 88) = 14.41, p \leq .001, \eta^2 = .25 \] (Figure 12b); post-hoc analysis showed participants liked more the CS1 \((M = 67.83, SD = 15.13)\) compared to the CS2 \((M = 43.9, SD = 21.8)\), \([t(44) = 4.98, p \leq .001, d = 1.28]\) and compared to the baseline \((M = 53.5, SD = 19.0)\), \([t(44) = 3.84, p \leq .001, d = 0.83]\). A tendency had been found between the baseline and the CS2, \([t(44) = 1.98, p = .052, d = 0.45]\), revealing that participants tended to press more for CS2 compared to baseline.
Figure 12b. The analog Pavlovian conditioning check. The y-axis illustrated the pleasantness ratings for the 3 pictures after the Pavlovian conditioning. The x-axis showed the type of Pavlovian stimuli. Error bars represented SEM. *** $p \leq .001$.

Transfer test
Effort mobilization was assessed by calculating 2 indicators:

1) Number of peak exceeding 50% of participant’s maximal force
2) Total force

1) Number of peaks exceeding 50% of participant’s maximal force

Based on previous research (Talmi et al., 2008; Pool et al., 2014), we calculated the number of squeezes exceeding 50% of participant’s maximal force to evaluate the effort mobilized to obtain a reward. A 2 (block: 1, 2) x 3 (image: CS1, CS2, baseline) x 3 (repetition: 1, 2, 3) repeated-measures analysis of variance (ANOVA) showed tendency in interaction between block and image: $[F(2, 88) = 2.38, p = .09, \eta^2 = .05]$. Post-hoc analysis on the first block, showed that the number of the squeezes tended to be higher for CS1 ($M = 10.10, SD = 1.82$) compared to CS2 ($M = 8.34, SD = 1.79$), $[t(45) = 1.86, p = .07, d = .98]$. This tendency became statistically significant in the second block where the number of peaks was statistically higher for CS1 ($M = 10.31, SD = 1.92$) compared to CS2 ($M = 8.12, SD = 1.74$), $[t(44) = 2.20, p = .03, d = 1.20]$. No statistical significant
difference was found between CS1 ($M = 10.10$, $SD = 1.82$) and baseline ($M = 9.97$, $SD = 1.81$) in the first block, $[t(44) = 0.12, p = .90, d = .07]$ or in the second block between CS1 ($M = 10.31$, $SD = 1.92$) and baseline ($M = 8.84$, $SD = 1.83$), $[t(44) = 1.23, p = .22, d = .78]$. No statistical significant difference was found in the first block between baseline and CS2, $[t(44) = -1.44, p = .157, d = -0.9]$, or in the second block, $[t(44) = -0.73, p = .47, d = .40]$. A difference between block 1 and block 2 was observed for baseline $[t(44) = 2.30, p = .03, d = .62]$, revealing a decrease in the number of squeezes. No statistical significant difference between block 1 and block 2 was found for CS1 $[t(44) = -0.42, p = .68, d = .12]$, or for CS2 $[t(44) = 0.57, p = .57, d = .12]$, revealing a constant effort for CSs stimuli (Figure 13).

**Figure 13.** Number of squeezes exceeding 50 % of the maximal force of the participant during the extinction phase of the transfer test. The left axis illustrates the number of squeezes performed by the participants. The right axis shows the type of Pavlovian stimuli and the number of block in which the squeezes were performed. Error bars represent SEM. *$p \leq .05$. 
2) Total force

A 2 (block: 1, 2) x 3 (image: CS1, CS2, baseline) x 3 (repetition: 1, 2, 3) repeated-measures analysis of variance (ANOVA) showed a significant effect of block \([F(1, 44) = 8.56, p = .0054, \eta^2 = .16]\), of repetition, \([F(2, 88) = 8.28, p \leq .001, \eta^2 = .16]\) and of a two-way interaction between block and image \([F(2, 88) = 4.099, p = .02, \eta^2 = .09]\).

The block effect showed a statistically significant decrease in the total amount of force from the first to the second block (Figure 14).

![Figure 14. Total amount of force during the extinction phase of the transfer test. Y-axis represented total force and x-axis the number of block (1, 2). Error bars represented SEM. * \leq .05.](image)

Post hoc analysis performed on the number of repetitions revealed that the force exerted on the handgrip decreased statistically significantly from the first \((M = 85.68, SD = 10.24)\) to the second repetition \((M = 75.94, SD = 11.09)\), \([t(44) = 3.51, p \leq .001, d = .91]\) and from the first to the third repetition \((M = 75.46, SD = 12.66)\), \([t(44) = 2.82, p \leq .01, d = .89]\), revealing a decline of the force from the beginning to the end of the experiment. No statistically significant difference had been found between the second and third repetition, \([t(44) = 0.27, p = .790, d = .04]\) (Figure 15).
Figure 15. Total force exerted during each repetition of the extinction phase of the transfer test. Y-axis represented total force and x-axis the number of repetition. Error bars represented SEM. *** $p \leq .001$ and ** $p \leq .01$.

The interaction between block and image showed a significant difference of the total force used in the two blocks for each Pavlovian stimulus. The only Pavlovian stimuli in which the exerted force did not decreased from the first to second block was the CS1. More precisely, in the first block, the strength exerted by the participants when the CS1 ($M = 80.74, SD = 9.33$) were presented at the screen did not statistically decreased compared to the tension exerted for CS1 ($M = 75.01, SD = 9.34$), $[t(44) = 1.32, p = .20, d = .61]$ in the second block, revealing a stable “wanting” to obtain this Pavlovian stimulus across blocks. The tension exerted on the handgrip by the participants for the baseline decreased significantly from the first ($M = 90.91, SD = 10.98$) to the second block ($M = 71.44, SD = 10.66$), $[t(44) = 3.42, p \leq .001, d = 1.80]$. The exerted force in the first block for the CS2 ($M = 82.38, SD = 14.17$) tended to decrease in the second block for the CS2 ($M = 73.69, SD = 11.72$), $[t(44) = -2.00, p = .052, d = .67]$. The reduction of the force exerted on the handgrip when the CS2 or the baseline appeared at the screen, revealed a decline in the motivation to obtain these stimuli. There was no statistically significant difference in the force in the first block between CS1 and CS2, $[t(44) = -0.25, p = .80, d = 0.14]$ or in the second block, $[t(44) = -0.18, p = .85, d = 0.13]$ (Figure 16).
Figure 16. Total exerted force during each block of the extinction phase of the transfer test for each Pavlovian Stimuli. Y-axis referred to the force and x-axis to the Pavlovian stimuli (CS1, CS2, baseline). CS1 corresponded to the abstract image associated to the mostly rewarding odour, CS2 corresponded to the abstract image associated to the mildly rewarding odour and Baseline to the abstract image with no odour associated. Error bars represented SEM. *** $p \leq .001$.

**Questionnaire data**

1) *Correlation between the number of peak (exceeding 50% of participant’s maximal force) and the anticipatory subscale of TEPS questionnaire*

A Pearson product-moment correlation coefficient was performed to investigate the relationship between frequency of squeezes during the extinction phase of the transfer test and the score to the anticipatory subscale of TEPS questionnaire. Analysis were performed on the mean of CS1, CS2, and baseline for the two blocks. There were no statistically significant correlation between anticipatory pleasure score and baseline, [$r(43) = 0.32, p = .75$], CS1, [$r(43) = 0.84, p = .40$] or CS2, [$r(43) = 0.61, p = .55$].
2) Correlation between the total force and the anticipatory pleasure subscale TEPS questionnaire

A Pearson product-moment correlation coefficient was computed to assess the relationship between the amount of total force during the extinction phase of the transfer test and the score to the anticipatory subscale of TEPS questionnaire. Analysis were performed on the mean of CS1, CS2, and baseline for the two blocks. No statistically significant correlation was found between the anticipatory scale and the amount of force exerted for CS1, \( r(43) = 0.08, p = .61 \), for CS2, \( r(43) = 0.08, p = .59 \) or for baseline, \( r(43) = 0.14, p = .35 \).

3.3.2.3 Discussion

The aim of this methodological experiment was to investigate the sensitivity of the PIT in order to measure cue-induced “wanting”. Our prediction was that this “wanting” would be larger for a picture associated with the most rewarding odour (CS1) than for a picture associated with less rewarding odours (CS2). We used procedures and concept operationalizations that were as comparable as possible to those used in research conducted on humans (Pool et al., 2015). We adapted an analogue of a human PIT, which originally used one olfactory reward (i.e., chocolate odour) to assess the effort mobilized to obtain multiple olfactory rewards. Participants successfully learned how to correctly squeeze the handgrip during the instrumental learning phase. The efficacy of the Pavlovian conditioning was confirmed by the liking test at the end of the Pavlovian phase: liking ratings of CS1 were higher than liking ratings of CS2. Concerning the RTs to the first target, no statistically significant difference between CS1 and CS2 was observed. However, we could not conclude that the Pavlovian conditioning occurred based on the RT indicator because we did not have a baseline (a neutral image without any associated odour) to compare the RTs for CS1 and CS2.

Concerning the transfer test, the two indicators of “wanting” revealed a preference for CS1 than for the other Pavlovian stimuli, but in two different ways. The indicator of the number of peaks showed that the cue-induced “wanting” was reflected by a larger increase in the effort mobilized during the presentation of CS1 than that during the presentation of CS2. More precisely, analysis on the first block showed that the effort mobilized to obtain a reward tended to be specific to rewarded properties (liking level) of the olfactory stimulus. In fact, the effort invested in instrumental action tended to be larger during the presentation of the Pavlovian stimuli that were
previously associated with the mostly rewarding odour (CS1) than that during the presentation of the Pavlovian stimuli previously associated with the mildly rewarding odour (CS2). The second indicator (total force) highlighted the difference in the exerted force for each Pavlovian stimulus. The only Pavlovian stimulus in which the exerted force did not decrease from the first to the second block was CS1, revealing a constant “wanting” to obtain this Pavlovian stimulus across blocks compared with the others. The number of squeezes performed by the participants for the baseline during the first block of the transfer test was not significantly different to that performed for CS1. This result is in line with the literature where it has been reported that no statistically significant difference between CS+ and baseline emerged, even though differences between CS+ and CS- had been highlighted (Cartoni, Balleine, & Baldassarre, 2016). These findings could be due to response competition between instrumental and Pavlovian responses. The reason behind this result could be the one illustrated by Cartoni and colleagues (2016): when an individual is performing a task requiring simultaneous instrumental and Pavlovian behaviours, they can be in competition and the presence of one decreases the effect of the other. The competition can positively or negatively affect the transfer effect.

In summary, these findings support our hypothesis that the measure of cue-induced “wanting” in the PIT is sensitive enough to exhibit significant differences as a function of the rewarding level of the unconditional stimuli.

Concerning our second objective, we did not find any statistically significant correlations between the individual trait in the anticipatory experience of pleasure and the two indicators of the “wanting” response in the PIT test. Such results should be taken cautiously because they correspond to a null finding and are consistent with the notion that expected pleasantness and “wanting” measures should indeed be considered as two distinct constructs as suggested in the literature (Pool et al., 2016).

In a second experiment, we further investigated the sensitivity of the PIT procedure by testing whether PIT may be sensitive enough to measure a potential difference in “wanting” for rewarding odours that differ only slightly in their liking levels as measured with a liking scale.
3.3.3 Experiment 2

Goal
The aim of Experiment 2 was again twofold: (1) to investigate whether the PIT procedure was a sensitive tool to differentiate the “wanting” between olfactory stimuli that differ slightly in liking levels and (2) to explore whether “wanting” correlated with expected pleasantness. Two odours with slight differences in liking levels were used: strawberry and tutti-frutti (bubble gum fragrance). In addition, to measure the individual trait in anticipatory experience of pleasure, the TEPS questionnaire (Gard et al., 2006) was used. We predicted that (1) participants would mobilize a higher effort to obtain the first mostly rewarding odour (CS1) than they would to obtain the second rewarding odour (CS2) in the transfer test and that (2) if expected pleasantness and “wanting” were two correlated concepts, individuals mobilizing more effort during the transfer test would have a higher score for expected pleasantness during questionnaire assessment.

3.3.3.1 Method and Materials

Participants. Fifty-four (11 men) subjects participated to the study, which was approved by the FPSE ethical committee of the University of Geneva. Healthy adults between 18 and 39 years old ($M_{\text{age}} = 23.8, SD_{\text{age}} = 5.21$) have been recruited from an online announcement on social networks. They had no history of psychiatric or neurological diseases, normal or corrected-to-normal vision, no olfactory problems and no smoking habits. The participants were paid 30 CHF for their participation. Participation required the completion of a consent form before the beginning of the experiment. The study was run in French and English.

Visual stimuli and Instrumental apparatus. The neutral images, the instrumental apparatus and the procedure for the delivering of the olfactory stimulation were the same as for experiment 1 (see chapter “Material” in the presentation of experiment 1).

Odour. Two odours (strawberry and tutti-frutti), provided by Firmenich, S.A., were selected from an initial set of 25 odours. In a preliminary test, the strawberry and the tutti-frutti fragrances have been evaluated on a VAS scale by 16 participants ($M_{\text{age}} = 28.2, SD_{\text{age}} = 3.78$) as having a similar pleasantness [$t(15) = 0.77, p = .50, d = .25$], intensity [$t(15) = 0.81, p = .40, d = .22$], familiarity [$t(15) = 0.55, p = .60, d = .19$] and edibility [$t(15) = 0.13, p = .90, d = .05$] levels (Table 3).
Table 3

The odours used in the second experiment

<table>
<thead>
<tr>
<th>Odours</th>
<th>Concentration (ml/l)</th>
<th>Dipropylene glycol (ml/l)</th>
<th>Mean Pleasantness (SD)</th>
<th>Mean Intensity (SD)</th>
<th>Mean Familiarity (SD)</th>
<th>Mean Edibility (SD)</th>
<th>Category</th>
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</thead>
<tbody>
<tr>
<td>Strawberry</td>
<td>2</td>
<td>8</td>
<td>7.81 (± 2.14)</td>
<td>6.84 (± 1.63)</td>
<td>8.06 (± 2.02)</td>
<td>6.80 (± 2.54)</td>
<td>Food</td>
</tr>
<tr>
<td>Tutti Frutti</td>
<td>5</td>
<td>5</td>
<td>8.35 (± 2.13)</td>
<td>6.49 (± 1.60)</td>
<td>8.40 (± 1.59)</td>
<td>6.93 (± 2.37)</td>
<td>Food</td>
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<tr>
<td>Empty</td>
<td>-</td>
<td>10</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>No odour</td>
</tr>
</tbody>
</table>

Note. The essences were provided by Firmenich, S.A., Geneva, Switzerland. The essences were dissolved in propylene glycol.

Procedure

Methodological adaptation

On the basis of the first experiment, we reduced the number of trials in the instrumental phase from 24 to 4 in order to have a shorter version that was more easily adaptable to various contexts. In fact, after giving the instruction on how to correctly use the handgrip and performing some training trials with the participants, individuals understood from the first trial of instrumental conditioning how to correctly press the power grip. We implemented and tested this change in the second experiment.

The same procedure as used in Experiment 1 was used here (see Table 4). Participants were asked to fill in a consent form, a demographic information questionnaire, and the TEPS in English (Gard et al., 2006) or in French (Favrod et al., 2009). They then rated the strawberry and tutti-frutti odours on a pleasantness, intensity, familiarity, and edibility scale (odour evaluation test). Later, they performed the PIT procedure with the very pleasant odours having slight differences in liking levels (strawberry and tutti-frutti).
Table 4  
*The experimental design of the second study*

<table>
<thead>
<tr>
<th>Instructions</th>
<th>Questionnaire</th>
<th>Odour evaluation</th>
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<th>Pavlovian</th>
<th>PIT</th>
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<td>Participation agreement, demographic information questionnaire</td>
<td>Evaluation of the 2 odours on 4 characteristics: intensity, pleasantness and familiarity, edibility</td>
<td>Instrumental training (4 trials)</td>
<td>Pavlovian conditioning (36 trials)</td>
<td>Transfer test (18 trials)</td>
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<th>7 minutes</th>
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*Note.* First participants filled in the consent form, the questionnaire on demographic information and the TEPS questionnaire. Secondly, participants performed an odour evaluation test on a computer screen. Two odours (strawberry and tutti-frutti) were used to perform the PIT paradigm. The total duration of the experiment was around 50 minutes. In the figure, the time is given for each part of the experiment.

### 3.3.3.2 Results

We applied the same criteria used in study 1 to include or exclude participant for the statistical analysis. No participants were excluded.

**Odour evaluation**

Paired *t* tests revealed that mean of the second rewarding odour (*M* = 69.06, *SD* = 12.49) was statistically lower than the mean of the first mostly rewarding odour (*M* = 72.70, *SD* = 14.43), [*t*(53) = 3.57, *p* ≤ .001, *d* = .27] (Figure 17a). The intensity mean of the second rewarding odour (*M* = 52.49, *SD* = 26.79), was statistically lower than the mean of the first mostly rewarding odour (*M* = 73.12, *SD* = 15.55), [*t*(53) = 4.73, *p* ≤ .001, *d* = .94] (Figure 17b).
Figure 17a. Distribution of the pleasantness scores of first mostly rewarding odour and the second rewarding odours (\(N = 54\)). The vertical axis illustrated the pleasantness scores at the VAS scale. The horizontal axis showed the type of odour (first mostly and second rewarding odour). Error bars represented SEM. *** \(p \leq .001\).

Figure 17b. Distribution of the intensity scores of first mostly rewarding odour and the second rewarding odours (\(N = 54\)). The vertical axis illustrated the intensity scores at the VAS scale. The horizontal axis shows the type of odour (mostly and less rewarding odour). Error bars represented SEM. *** \(p \leq .001\).
Instrumental conditioning

We calculated the number of squeezes exceeding 50% of participant’s maximal force in order to assess the effort mobilized to obtain a reward (Talmi et al., 2008; Pool et al., 2014). A repeated-measures analysis of variance (ANOVA) ran on the 4 trials did not show a trial effect, $[F(3,159) = 1.23, p = .30, \eta^2 = .02]$, revealing that from the beginning, the participants pressed sufficiently to perform the task after a short training phase (Figure 18).

![Instrumental conditioning](image)

**Figure 18.** Instrumental conditioning. The number of times participants ($N = 54$) squeezed the handgrip is displayed as a function of trials over time. The y-axis illustrated the number of squeezes exerted by the participants. The x-axis showed the number of trials performed by the participants.

Analog of Pavlovian conditioning

Successful Pavlovian contingency learning was assessed by reaction time (RT) of the key-pressing task (Figure 19a) and by likability rating of the CSs (Figure 19b) indicators.

Reaction time (RT) indicator

For the key-pressing task, we analysed RTs on the first target of the task-on period. The results show that during the first trial, the RTs for the CS1 ($M = 414.04, SD = 51.55$) tended to be higher compared to the RTs for CS2 ($M = 400.01, SD = 57.43$), $[t(53) = 1.94, p = .06, d = .26]$ (Figure 19a).
Figure 19a. The analog Pavlovian conditioning results for the key-pressing task. The y-axis illustrated the reaction time to detect the cue during the presentation of the first mostly positive conditioned stimulus (CS1) and the second positive conditioned stimulus (CS2). The x-axis illustrated Pavlovian stimuli (CS1 and CS2). Error bars represented SEM.

Likability rating indicator

At the end of the conditioning procedure, participants evaluated the pleasantness of the images used (CS1, CS2, and baseline) on a VAS (from 0-extremely unpleasant to 100-extremely pleasant). The images were presented randomly after the conditioning phase at the centre of the computer screen. A repeated-measures analysis of variance (ANOVA) applied to the likability ratings of the three Pavlovian images (CS1, CS2, and baseline) revealed a significant effect of image, \( F(2, 106) = 6.98, \ p \leq .01, \eta^2 = 0.12 \). Post-hoc analysis showed that the subjects liked more the CS1 (\( M = 61.9, SD = 2.15 \)) compared to the baseline (\( M = 51.7, SD = 3.01 \)), \( t(53) = -2.84, p \leq .01, d = -3.90 \). The subjects liked more the CS2 (\( M = 64.7, SD = 2.16 \)) compared to the baseline too \( t(53) = -3.18, p \leq .01, d = -4.96 \). There was not a statistically difference between the CS1 compared to the CS2 \( t(53) = -0.86, p = .39, d = 1.29 \), indicating that participants did not like more the CS images previously associated with the first mostly rewarding odours compared to the CS images previously associated with the second rewarding odour (Figure 19b).
Figure 19b. The analog of the Pavlovian conditioning likability results. The vertical axis illustrated the pleasantness ratings for the 3 Pavlovian Stimuli after the Pavlovian conditioning. The horizontal axis showed the type of Pavlovian stimuli. Error bars represented SEM. ** $p \leq .01$.

Transfer Test

As for the experiment 1, two indicators were developed to measure “wanting” during the extinction phase of the transfer test such as number of peak exceeding 50% of participant’s maximal force and integral of the total force.

1) Number of peaks exceeding 50% of participant’s maximal force

We calculated the number of squeezes exceeding 50% of participant’s maximal force in order to assess the effort mobilized to obtain a reward (Pool et al., 2015; Talmi et al., 2008).

A 2 (block: 1, 2) x 3 (image: CS1, CS2, baseline) x 3 (repetition: 1, 2, 3) repeated-measures analysis of variance (ANOVA) showed an effect of repetition [$F(2, 106) = 4.11, p \leq .01, \eta^2 = .07$].

The number of peak was stable from the first ($M = 11.52, SD = 1.93$) to the second repetition ($M = 11.57, SD = 2.03$), [$t(53) = -0.18, p = .85, d = .03$]. Then, it started to decline from the second to the third repetition ($M = 10.83, SD = 1.94$), [$t(53) = 2.87, p = .0059, d = .37$]. A main difference was found between the first to the third repetition [$t(53) = 2.08, p \leq .05, d = .36$], revealing that the number of peak decreased significantly from the beginning to the end of the extinction phase.
of the transfer test. No effect was found for image $[F(2, 106) = .38, p = .69, \eta^2 = .007]$, indicating no statistical significant difference in the total amount of squeezes exerted when CS1, CS2 and baseline were at the screen. In addition, no statistical significant difference was found between CS1 in block 1 ($M = 11.64, SD = 1.41$), and CS1 in block 2 ($M = 11.40, SD = 1.57$), $[t(53) = 0.50, p = .61, d = .16]$. No statistical significant difference was found between CS2 in block 1 ($M = 11.39, SD = 1.45$), and CS2 in block 2 ($M = 10.90, SD = 1.51$), $[t(53) = 0.76, p = .45, d = .33]$. No statistical significant difference was found between baseline in block 1 ($M = 11.57, SD = 1.52$), and baseline in block 2 ($M = 10.95, SD = 1.52$), $[t(53) = 1.51, p = .14, d = .41]$ (Figure 20).

![Chart](image)

**Figure 20.** Number of squeezes exceeding 50% of the maximal force of the participants during each repetition of the extinction phase of the transfer test. Y-axis corresponded to number of squeezes and x-axis to number of repetition (1, 2, 3). Error bars represented SEM. **$p \leq .01$ and *$p \leq .05$.**

2) **Total force**

A 2 (block: 1, 2) x 3 (image: CS1, CS2, Baseline) x 3 (repetition: 1, 2, 3) repeated-measures analysis of variance (ANOVA) showed a statistically significant effect of block, $[F(1, 53) = 19.0, p \leq .001, \eta^2 = .26]$ and of repetition, $[F(2, 106) = 4.27, p = .02, \eta^2 = .07]$. The block’s effect showed that the total amount of force decreased significantly from the first to the second block (Figure 21).
Figure 21. Integral of the total amount of force during the extinction phase of the transfer test. Y-axis represented total force and x-axis number of block (1, 2). Error bars represented SEM. *** $p \leq .001$.

The repetition’s effect showed that the force exerted on the handgrip decreased significantly from the first to the third repetition. More precisely, post-hoc analysis showed a difference in the force from the first ($M = 90.91, SD = 9.70$) to the third repetition ($M = 85.50, SD = 10.97$), $[t(53) = 2.81, p \leq .01, d = .49]$ indicating a decrease of the total amount of force exerted from the beginning to the end of the test. No statistical significant difference was observed between the first and the second ($M = 88.50, SD = 9.89$) repetition $[t(53) = 1.33, p = .19, d = .25]$ or between the second and the third repetition $[t(53) = 1.67, p = .10, d = .26]$ (Figure 22).

Figure 22. Total force exerted during each repetition of the extinction phase of the transfer test. Y-axis corresponded total force and x-axis to number of repetition (1, 2, 3). Error bars represented SEM. ** $p \leq .01$. 
No statistically significant difference was found in the total force between the three Pavlovian stimuli \([F(2,106) = 1.12, p = .33, \eta^2 = .02]\). In addition, a difference between CS1 in the block 1 \((M = 93.63, SD = 7.53)\) and CS1 in block 2 \((M = 88.15, SD = 8.61)\) was found \([t(53) = 2.04, p \leq .05, d = .68]\), revealing a decrease in the total force exerted when the CS1 was show at the screen in the block 2. A statistically significant difference was observed between the force exerted for CS2 in the first block \((M = 93.50, SD = 8.02)\) and CS2 in the second block \((M = 83.15, SD = 8.14)\) \([t(53) = 2.84, p \leq .01, d = .28]\), indicating a decline of the force for this stimulus too. A statistically significant difference was observed between the force exerted for baseline in the first block \((M = 91.25, SD = 8.54)\) and baseline in the second block \((M = 80.80, SD = 8.06)\) \([t(53) = 3.89, p \leq .001, d = 1.26]\), indicating a decline of the force for this stimulus too (Figure 23).

**Figure 23.** Total force exerted for Pavlovian stimuli in the two blocks. The y-axis illustrated the total force exerted by the participants. The x-axis showed the number of block in which the force was exerted. Error bars represented SEM. * \(p \leq .05\), ** \(p \leq .01\) and *** \(p \leq .001\).
Questionnaire data

1) *Correlation between the number of peak (exceeding 50% of participant’s maximal force) and the anticipatory subscale of TEPS questionnaire*

A Pearson product-moment correlation coefficient was performed to investigate the relationship between the score to the anticipatory subscale of TEPS questionnaire and the frequency of squeezes during the extinction phase of the transfer test. Analysis were performed on the mean of CS1, CS2, and baseline for the two blocks. No statistically significant correlation was found between the anticipatory pleasure score and CS1 \[ r(53) = -0.38, p = .70 \], CS2, \[ r(54) = -0.17, p = .89 \] or baseline \[ r(53) = -0.16, p = .87 \].

2) *Correlation between the total force and the anticipatory subscale of TEPS questionnaire*

A Pearson product-moment correlation coefficient was performed to investigate the relationship between the score to the anticipatory subscale of TEPS questionnaire and integral of the total force during the extinction phase of the transfer test. Analysis were performed on the mean of CS1, CS2, and baseline for the two blocks. No statistically significant correlation was found between the anticipatory pleasure score and CS1 \[ r(52) = -0.90, p = .37 \], CS2, \[ r(52) = -0.60, p = .55 \] or baseline \[ r(52) = -0.18, p = .85 \].

3.3.3.3 Discussion

The aim of Experiment 2 was twofold: (1) to investigate whether differences in “wanting” may still be observed for odours that slightly differ in liking levels and (2) to empirically investigate whether the individual trait to anticipate how pleasant or unpleasant something is going to be in the future (expected pleasantness) correlated with the “wanting” response in the PIT test.

From the descriptive and statistical analyses, participants squeezed the handgrip correctly from the first trial until the last trial. In addition, the likability check showed that participants liked the CS images more than they did the baseline, indicating successful Pavlovian conditioning. The RT indicator did not show any statistical difference between CS1 and CS2. However, we could not conclude that the Pavlovian conditioning occurred based on the RT indicator because we did not
have a baseline (a neutral image without any associated odour) to compare the RTs for CS2 and CS1.

Concerning the first objective, we again replicated the transfer effect and were able to measure a “wanting” response despite the change in our procedure in terms of number of trials. However, the “wanting” measure did not reveal any statistical difference in the effort mobilized to obtain one odour than that mobilized to obtain the other. Results suggest that the force indicator may be more precise than the indicator for the number of peaks, as it revealed a specific statistical decline in motivation (which was different for each Pavlovian stimulus) across blocks that was not observed when we analysed the number of peaks. In addition to this objective, we wanted to measure the correlation between the anticipatory trait and the “wanting” score during the PIT test. We did not find any significant correlation between the anticipatory pleasure subscale of the TEPS questionnaire and the “wanting” indicators during the extinction phase of the transfer test.

3.3.4 General Discussion

Animal studies have suggested that reward processing involves multiple components (such as “liking” and “wanting”) and that the “liking” component can be measured independently from the “wanting” component (Berridge 2009a, 2009b; Robinson & Berridge (1993); Berridge & Robinson, 2003). A key procedure used to explore the “wanting” component in animals and humans is the PIT. This procedure helps one to investigate reward processing in the laboratory by studying “wanting” outside of consummatory pleasure. In a previous experiment, our laboratory demonstrated the validity of the PIT procedure to dissociate the “wanting” associated with a rewarded stimulus (CS+) from that associated with a non-rewarded stimulus (CS-) in a chemosensory setting (Pool et al., 2015). In this article, we presented the results of two studies performed to further investigate the sensitivity of the PIT procedure by using odours with different rewarding properties (measured on a liking rating scale). In both experiments, two “wanting” indicators were used. The number of peaks and the total force used to press the handgrip. Each of them showed the same pattern but in two different ways. In the first experiment, our findings demonstrated that the effort mobilized to obtain a reward was specific to rewarded properties of the olfactory stimuli. We selected odours with a mean difference of 21.19 points on a valence scale of 100 points. The results from the first indicator (number of peaks) showed that the effort invested in instrumental action was larger during the presentation of the visual stimulus previously
associated with the mostly rewarding odour (CS1) than for that during the presentation of the visual stimulus previously associated with the mildly rewarding odour (CS2). The results from the second indicator (total force) highlighted that, from the first to the second block, the force remained stable only for CS1, whereas it decreased for CS2 and the baseline, suggesting a more stable motivation for this Pavlovian stimulus. The findings of the first experiment demonstrated that it is possible to measure the effort mobilized to obtain two different rewarding stimuli (one not very rewarding and the other very rewarding) by means of the PIT procedure.

With the second experiment, we further investigated the sensitivity of the PIT procedure by using odours with a smaller difference in liking levels. More specifically, we used two pleasant food odours (strawberry and tutti-frutti) with a statistical mean difference of 5.4 points on a valence scale of 100 points. Results showed a similar quantity of effort mobilized during the presentation of visual stimuli previously associated with odours having a slight difference in liking levels. The explanation for these results may be twofold. On the one hand, we did not find a difference in the effort mobilized for CS1 and CS2, because PIT was not sensitive enough to dissociate the “wanting” associated with stimuli having slight differences in liking levels. In this case, the PIT paradigm cannot be considered a valid method to measure “wanting” for odours having a slight difference in reward properties. On the other hand, we can assume that there was no true difference in the amount of effort mobilized to obtain CS1 and CS2 that can be detected by this measure. This hypothesis can be supported by the literature. In fact, from a theoretical point of view, the effort mobilized during an action should be adapted to the environment (Frijda, 1987; Sander, Grandjean, & Scherer, 2005). If two stimuli in the environment have slight differences in liking levels, an organism will invest the same amount of effort to obtain one or the other. From this perspective, the effort mobilized for two similar olfactory stimuli is different only if the two stimuli induce different behavioural adaptations to changes in the environment. If the stimuli do not cause a different behavioural adaptation, the organism will mobilize the same amount of effort. We can assume that in our second experiment, the rewarding properties of the two stimuli were not much different for the participants; consequently, the effort mobilized by the subjects was the same. The reason behind this can be related to the family of odours: we used two food odours. This implies that the basic drive behind the choice of one odour or the other was similar.

In summary, the PIT procedure was able to dissociate “wanting” for olfactory stimuli that were highly different in liking levels. Moreover, we can assume that when two slightly different
olfactory pleasant odours from the same family are compared, the PIT test may not provide additional information in an industrial setting than that provided from a liking measure. However, to assess the impact of odour categories on the sensitivity of PIT, further research should be done. Consequently, it would be valuable to test our second hypothesis by using odours with slight differences in liking levels but from different families (animal, food, and/or cosmetic odours) and in contexts that increase the pertinence of one category over another. In that case, the effort observed can be different because the function of the odours diverges. For instance, a potential way to test this is by considering the physiological state (hungry, satiety) of a subject and by using food and non-food odours. In addition, it would be interesting to test the model in a gustatory-olfactory experiment in which liquids are used to increase the ecological nature of the experiment. Finally, another important point to consider is the effort to mobilize asked of the participants in a task. In fact, one animal study showed that the number of lever presses required to obtain a food reward is crucial in the “wanting” response of obese mice: they respond more when two lever presses are required to obtain a food reward, but less when 50 are needed (Atalayer, Robertson, Andreasen, Haskell-Luevano, & Rowland, 2010). Thus, different criteria could be used to define the release of olfactory rewards. Another notable result concerned the two indicators used to operationalize the “wanting” component. In the first experiment, the number of peaks and the force indicators highlighted the same patterns. In the second experiment, the force indicator showed additional information about the way participants performed the PIT task: they continued to press the handgrip for all the Pavlovian stimuli, but their perseverance in pressing it from block 1 to block 2 decreased significantly for each of them. The loss of motivation from one block to the other was generalized to the entire task.

In addition to this first objective, we investigated whether the concept of expected pleasantness and of “wanting” correlated. In both experiments, we did not find a statistically significant correlation between the individual trait in anticipatory experience of pleasure and the two indicators of the “wanting” response in the PIT test. Such results should be taken cautiously because they correspond to a null finding and are consistent with the assumption that these two measures corresponded to two unique concepts as suggested in the literature (Pool et al., 2016). Some limitations of the two experiments must be highlighted. The adaptation of the PIT procedure to human research has led to the need to develop instructions (presented on the screen or verbalized by the investigator) for the participants. Animals did not receive instructions and no external
influences were allowed in the animal PIT procedure. We can assume that using instructions pushes the participants to easily and consciously understand the goal of the task. Further research is needed regarding this aspect.

Conclusion

The present study supported the conceptualization that the PIT paradigm showed sensitivity for detecting the effort mobilized (“wanting”) for two odours with different levels of liking. Moreover, when two slightly different olfactory pleasant odours from the same family are compared, the PIT test may not provide additional information than that provided from a liking measure. In addition, an exploratory investigation of the correlation between “wanting” and expected pleasantness highlighted the possibility that the two notions corresponded to two unique psychological concepts as suggested in the literature (Pool et al., 2016).

In the following two experiments, we tested sensitivity of PIT paradigm to measure “wanting” by manipulating salience of odours through contexts modification. In the first study (experiment 3 of this thesis), we investigated the sensitivity of PIT paradigm to measure “wanting” for cosmetic compared to food olfactory rewards after a disgust priming task. In the second study (experiment 4 of this thesis), we manipulated the satiety physiological state and measured the sensitivity of the PIT task to measure “wanting” for food compared to cosmetic olfactory rewards.
3.4 EXPERIMENT 3

Investigating the sensitivity of PIT paradigm to measure “wanting” for cosmetic olfactory rewards after a disgust priming task

Abstract

According to Incentive Salience Theory (IST), approach or avoidance motivation to a stimulus is determined by individual’s goal in certain situations (Berridge et al., 2007; Zhang et al., 2009). The Pavlovian to Instrumental Transfer (PIT) paradigm was used in animal and recently in human to test this hypothesis. In olfactory domain, it has been used only with a single olfactory pleasant reward (Pool et al., 2016).

In this experiment, we wanted to test the sensibility of the PIT paradigm to measure difference in “wanting” to obtain olfactory rewards when individual’s goal changed. We developed a disgusting surrounding environment provoking physical disgust, to investigate if momentary individual’s goal amplified the motivation (“wanting”) to obtain stimuli covering potential environmental hazards or being associated with that goal such as for instance cleansing/cosmetic compared to food stimuli.

Despite disgust priming occurred, our findings showed that PIT paradigm was not able to highlight an amplified “wanting” for cleansing/cosmetic stimuli compared to food stimuli. A more quickly disengaged to perform effort task was observed in disgusted individuals compared to controls.
3.4.1 Introduction

According to Incentive Salience Theory (IST), pursuit of a positive outcome (reward) is influenced by pleasure felt during consumption of it (liking), motivation to obtain it (wanting) and automatic associations or cognitive representations of reward (learning) (Robinson & Berridge, Robinson, 1998, Robinson & Berridge, 2003; Berridge & Kringelbach, 2008; Berridge, Robinson, & Aldridge, 2009). Together, these components defined the reward system and modulate how subjects responded to rewarding and aversive stimuli. Motivational component has widely been studied in rodents, but it is only little investigated in humans. Pavlovian to Instrumental Transfer (PIT) is a paradigm used in rodent and human to investigate the implicit facet of motivational component of the reward system (“wanting”). The procedure enables to study experimentally the “wanting” on the absence of the liking component.

Research on motivational component indicated that approach or avoidance motivation to a stimulus is determined by individual’s goal in certain situations (Berridge et al., 2007; Zhang et al., 2009). For instance, when doing gardening, a sudden change in subjective physical disgust feeling level could be due to the touch, observation and smell of a dead animal in the garden. The information derives from the different senses such as the strong stench of dead animal decomposition, could potentially provoke the development of physical disgust feeling and an urge to find cleansing elements to cover this strong negative emotion.

Among the different senses, the sense of smell in human has the function to avoid environmental hazards. Environmental chemical hazard signals include nonmicrobial (e.g. predators, fire, degraded air, and poisons) and microbial (e.g. faeces, vomit, sexual substances and organic decay) threats signals. In human, each category has been associated to a specific emotion such as disgust for microbial hazards (Stevenson, 2010). Certain microbial threats eliciting disgust in human, provoke more largely avoidance behaviour in animals too, because potentially contain infectious pathogens (Curtis & Biran, 2001).

3 In Stevenson’s classification of chemical environmental hazards, the signals of danger related to food for ingestion are not part of nonmicrobial hazards, because environmental hazards are salience irrespective of organism’s motivational state and result in specific response such as movement away from contaminants or open areas and psychological and physiological arousal.
Disgust increases the chances that surrounding element in the environment becomes detected and further identified (Keller, 2014; Stevenson, 2009) and motivates an individual to approach or avoid that specific environmental component. Elliot (2008) defined avoidance motivation as “the energisation of behaviour, or the direction of behaviour away from, negative stimuli” compared to approach motivation that is defined as “the energisation of behaviour, or the direction of behaviour toward, positive stimuli (objects, events, possibilities)” (p. 8). Motivation activates and directs behaviour and thus facilitates survival of organisms.

Originally, disgust evolved as a response to unpleasant food causing harm or carrier disease to the organism (Wicker et al., 2003; Sherman et al., 2011). Pioneers authors exploring the concept of disgust, put it in relation with the sense of taste and focused attention to mouth and to real or imaged ingestion (Darwin, 1872; Angyal, 1941; Rozin & Fallon, 1987). Later, disgust was defined as an emotional response of revulsion to something considered as offensive for an organism, an emotion to protect body from germs, parasites and being associated to “anything” which caused a revulsion feeling by sense of smell, touch or vision. Therefore, research on disgust are nowadays extended to social and moral domains too (Rozin, Haidt, & McCauley, 2000).

Today, research in psychology and neuroscience has discovered a wide variety of cross-cultural elicitors of disgust. Scientists have developed categories of stimuli eliciting disgust such as food (spoiled foods), animals (worms, flies, rats etc.), body products (faeces, vomit, saliva, mucus, urine and sexual fluids), injuries/infections (blood, mutilation), death (organic decay and dead bodies), hygiene (lack of cleanliness on body or on surgical instruments) and elicitors related to moral values (such as sexual aggression, abuse on children and murder etc.). Interestingly, experience of physical and moral disgust involves similar neural structures (Moll et al., 2005). Disgust stimuli can provoke nausea, avoidance reactions and specific facial expressions recognizable across cultures (Ekman et al., 1972; Rozin et al., 1994).

Disgust is a negative emotion which influences different aspects of our daily live and our well-being. More generally, disgust is a barrier for the development of interest (Bixler & Floyd, 1999), negatively impacts existing interest, self-efficacy beliefs and it is detrimental for intrinsic motivation in academic settings (Pekrun et al., 2002; Hostermann et al., 2009). For instance, Randler et al. (2013) investigated the link between situational disgust and motivation during a course at the university. Author studied how perceived disgust of living animals, prepared mounts or dissection lessons influenced student’s motivation and achievement. Results showed that the
most disgusting lessons were the ones with living animals and were a trout was dissected. The least disgusting were the ones with no living animals or very small animals. Disgust correlated negatively with interest, well-being, and motivation and positively with pressure and boredom.

As presented previously in the example of gardening, in a disgusting surrounding environment provoking physical disgust, a potential goal-directed behaviour could be to find and obtain stimuli covering potential environmental hazards or being associated with that goal such as for instance cleansing products (i.e. soap to clean the hands). In the following experiment, we tested in laboratory this potential effect of momentary physical disgust on implicit motivation to obtain relevant cosmetic olfactory rewards to cope with the negative emotion. The implicit motivation was measured by means of the PIT paradigm where cosmetic and food olfactory rewards were used. Our principal goal was to test the sensibility of the PIT paradigm to highlight difference in “wanting” for relevant and no relevant rewards.

In line with experiment 1 and 2 of this thesis, our second objective was to exploratory investigate whether exist a relationship between the concept of expected pleasantness and of “wanting”.

**Objectives**

According to the incentive salience theory, individual’s goal state determines either approach or avoidance motivation (Berridge et al., 2007; Zhang et al., 2009). In a disgusting surrounding environment provoking physical disgust, a potential goal-directed behaviour could be to find stimuli covering potential environmental hazards or being associated with that goal such as for instance cleansing products (i.e. soap to clean the hands). Such environmental cues may, according to the IST acquire a particular salience and individual may invest more effort to obtain reward associated to those cues. A potential way to test this hypothesis would be to use the Pavlovian to instrumental transfer (PIT) test. It provides a measure of the effort engaged to obtain a reward (“wanting”) without asking explicitly the cognitive desire pushing the participant to obtain it. The “wanting” measure is done outside and after the consummatory phase (liking phase). In our laboratory, we used this procedure in the presence of one olfactory stimulus and in presence of two stimuli. Results showed that the procedure efficiently highlight the motivation (“wanting”) in the presence of a single olfactory sweet reward (Pool et al., 2014), of two olfactory rewards with
very different rewarded proprieties but failed in the presence of two olfactory rewards of the same category and with similar rewarded characteristics (Chillà et al., in prep). Based on the previous results and on the literature, we proposed to investigate further the sensitivity of the PIT paradigm in the chemosensory field. Specifically, the sensitivity was tested in the presence of two odours with similar rewarding properties but from different families (no-cosmetic and cosmetic odours) and in a context, that increased the pertinence of one category compared to the other. To the end, we created a disgust-priming task to evoke participants’ physical disgust feeling and to make cosmetic related olfactory stimuli to become highly relevant and rewarding for the momentary individual goal of covering potential environmental hazards. A neutral priming task (no-disgust) was created as control condition. The consummatory pleasure (liking) for the two pleasant odours was similar. “Wanting”, to obtain olfactory stimulations, was measured during the transfer test of the PIT procedure. We assumed that the “wanting” for the cosmetic-related odours would increase for participants performing the disgust-priming test compared to participants in the control group.

In addition to this first objective, we exploratory investigated whether “wanting” correlated with expected pleasantness. According to Pool and colleagues (2016), expected pleasantness referring to the expectations of how pleasant or unpleasant something is going to be in the future. The authors suggested that this concept differed from liking and wanting components. In this experiment, we wanted to exploratory investigate this suggestion. We measured expected pleasantness, by means of the Temporal Experience of Pleasure Scale (TEPS) (Gard et al., 2006), where individual trait to image a potential pleasurable event was measured and we correlated this score to “wanting” score. We assumed that if the two concepts were correlated, individuals having a higher score for expected pleasantness, would mobilize more effort in the PIT test. If the two concepts were not correlated, the expected pleasantness score did not co-vary with effort mobilization.

3.4.2 Method and Materials

Participants. We invited 81 individuals to participate to the experiment at Firmenich, S.A. (Geneva, Jonction). They had no history of psychiatric, neurological diseases or eating disorders. They had normal or corrected-to-normal vision, no reported olfactory problems, no smoking habits and were not following a diet. They were aged between 18 and 40 years old ($M_{age} = 24$, $SD_{age} =$
4.87). Five participants were later excluded based on experimental criteria (see results section) leaving 76 subjects for analysis. Participants were instructed not to eat or drink anything (apart from water) at least 1.5 hours before testing in order to have all subjects in same condition.

**Visual stimuli.** Visual stimuli were different according to the phase of the experiment. In the priming tasks, we used 70 standardised visual stimuli from the initial set consisting on 240 images of the DIsgust-RelaTed-Images (DIRTI) Database (Haberkamp et al., 2016). In the disgust-priming task participants watched 35 visual stimuli of disgust of the following categories: animals, body products, injuries/infections, death, and hygiene. These images were supposed to induce a general feeling of disgust and more in particular a physical feeling of disgust. Spoiled food category was excluded from stimuli to avoid any signals of dangerous that were not part of the environmental hazards. In the neutral-priming task, 35 neutral visual stimuli of the same categories were used. All the images were luminance control.

In the PIT task, 4 figures from an initial set of 33 have been used (Chillà et al., in prep.). Three were used in the Pavlovian phase, one in the instrumental phase (see experiment 1, chapter visual stimuli for more details).

**Olfactory stimuli.** The following eight olfactory stimuli have been provided by Firmenich: butter popcorn, strawberry, malt chocolate, citrus parfum, floreal parfum, jasmin, galbex and feacal odours (Table 5).

We used reconstitution of fecal odour as malodour reconstitution in the disgust priming task and galbex as neutral odour in no-disgust priming task. The other odours have been used in the odour evaluation task and in the PIT test. A pre-test on 15 individuals \(M_{age} = 31.58, SD_{age} = 6.21\) was performed to evaluate the pleasantness, intensity, familiarity and edibility of each odour. The odours were evaluated by means of on intensity, pleasantness, edibility and familiarity on a 10-point Likert scale (from 0—“not pleasant/not intense/not familiar/not edible at all” to 10—“extremely pleasant/intense/familiar/edible”).
Table 5
The odours used for the study

<table>
<thead>
<tr>
<th>Odours</th>
<th>Concentration (ml/l)</th>
<th>Dipropylene glycol (ml/l)</th>
<th>Mean Pleasantness (SD)</th>
<th>Mean Intensity (SD)</th>
<th>Mean Familiarity (SD)</th>
<th>Mean Edibility (SD)</th>
<th>Category</th>
</tr>
</thead>
<tbody>
<tr>
<td>Butter Popcorn</td>
<td>5</td>
<td>5</td>
<td>8.85 (±1.25)</td>
<td>8.36 (±2.13)</td>
<td>8.36 (±2.13)</td>
<td>8.36 (±2.13)</td>
<td>Food</td>
</tr>
<tr>
<td>Strawberry</td>
<td>2</td>
<td>8</td>
<td>8.89 (±1.99)</td>
<td>7.50 (±1.55)</td>
<td>8.24 (±1.04)</td>
<td>8.99 (±1.86)</td>
<td>Food</td>
</tr>
<tr>
<td>Melt chocolate</td>
<td>2</td>
<td>8</td>
<td>8.65 (±1.68)</td>
<td>8.85 (±1.45)</td>
<td>8.77 (±2.05)</td>
<td>8.56 (±2.00)</td>
<td>Food</td>
</tr>
<tr>
<td>Citrus Parfum</td>
<td>2</td>
<td>8</td>
<td>8.55 (±1.96)</td>
<td>7.63 (±1.40)</td>
<td>9.01 (±1.78)</td>
<td>7.42 (±2.41)</td>
<td>Cosmetic</td>
</tr>
<tr>
<td>Floral Parfum</td>
<td>5</td>
<td>5</td>
<td>8.41 (±2.14)</td>
<td>7.30 (±2.03)</td>
<td>7.46 (±2.55)</td>
<td>5.44 (±2.73)</td>
<td>Cosmetic</td>
</tr>
<tr>
<td>Jasmin</td>
<td>5</td>
<td>5</td>
<td>8.37 (±1.68)</td>
<td>7.21 (±2.11)</td>
<td>7.99 (±2.02)</td>
<td>5.01 (±1.01)</td>
<td>Cosmetic</td>
</tr>
<tr>
<td>Galbex</td>
<td>5</td>
<td>5</td>
<td>4.92 (±2.93)</td>
<td>6.29 (±2.22)</td>
<td>6.46 (±2.90)</td>
<td>4.13 (±3.39)</td>
<td>Cosmetic</td>
</tr>
<tr>
<td>Faecal</td>
<td>1</td>
<td>9</td>
<td>2.03 (±1.58)</td>
<td>7.52 (±1.43)</td>
<td>8.01 (±2.43)</td>
<td>1 (±0.5)</td>
<td>Animal</td>
</tr>
<tr>
<td>Empty</td>
<td>-</td>
<td>10</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>No odour</td>
</tr>
</tbody>
</table>

Note. The essences were provided by Firmenich, S. A., Geneva, Switzerland. The essences were dissolved in propylene glycol. Faecal term corresponded to faecal odour reconstitution, that we created internally at Firmenich S. A..

Olfactory apparatus. All olfactory stimulations were rapidly delivered through a computer-controlled olfactometer with an airflow fixed at 1 L/min, without thermal and tactile confounds and via a nasal cannula (Ischer et al., 2014; Pool et al, 2014; Chilla et al, in prep.).

Instrumental apparatus. The measure of the effort mobilized (“wanting”) to obtain the different stimuli has been done through an isometric handgrip dynamometer (TSD121C), that participants were requested to press. The dynamometer was connected to the MP150 Biopac Systems (Santa Barbara, CA) and data recorded (sampling rate 60Hz) using MATLAB (version 8.0). The instrumental apparatus was used during the instrumental and transfer phases. The participants received a visual online feedback concerning the force they exerted on the handgrip (Psychtoolbox 3.0). This feedback consisted of an image of a thermometer displayed on the left side of the screen (30° visual angle). The “mercury” of this thermometer-like image moved up and down according
to the mobilized effort exerted by the participant. The “mercury” reached the top of the scale if the handgrip was squeezed with at least 50 % or 70 % of the maximal force of the participant (randomly chosen for each strength data point).

**Questionnaires.** The following questionnaires were used in the experiment: 1) Consent form, 2) Demographic questionnaire, 3) Eating Attitudes Test (EAT-26; Garner, 1982), 4) Positive and Negative Affect Schedule (PANAS; Watson, Clark, & Tellegen, 1988), 5) Temporal Experience of Pleasure Scale (TEPS; Favrod et al., 2008), 6) emotional and physiological questionnaires.

We collected individual’s general information (such as age, sex, body mass index) through the demographic questionnaire. We used the Eating Attitudes Test to assess eating disorder risk. It was a self-report questionnaire with 26-item measuring symptoms and concerns characteristic of eating disorders. Positive and Negative Affect Schedule allowed us to measure positive and negative affects. It was a two 20-item self-report (from 1- “not at all” to 5- “very much”). We used the French version of the Temporal Experience of Pleasure Scale to evaluate individual traits in anticipatory and consummatory experiences of pleasure. The TEPS included two 6-point Likert scales (from 1-“very false for me” to 6-“very true for me”) measuring distinct constructs: the anticipatory and the consummatory scale. Specifically, the first scale was related to reward responsiveness and imagery, and the second scale was related to openness to different experiences, and appreciation of positive stimuli. We developed an emotional and physiological questionnaire to evaluate across the entire experiment some specific information concerning emotions such as happiness, sadness, scariness, angry, disgust, but also the feeling to clean hands, feeling of dirty and physiological reactions such as hunger, tiredness, fullness and arousal. Each emotion and/or feeling was measured through a visual analogue scale (VAS) (from 1-“not at all” to 10-“very much”).

**Procedure**

Participants were randomly assigned to disgust ($N = 41$) or to no-disgust condition ($N = 40$). To manipulate salience of cue without altering learning processes, priming tasks where performed after Pavlovian and Instrumental trainings. The duration of the experiment in each condition was of 1 hour and 30 minutes. Participants received 30 CHF for their participation.
For both conditions

Upon arrival at the laboratory, participants were provided with written information about the study and were asked to read and sign the informed consent. Participants started with some demographic questions and completed Eating Attitudes Test (EAT-26), Positive and Negative Affect Schedule (PANAS), Temporal Experience of Pleasure Scale (TEPS), emotional and physiological questionnaires.

Later, they evaluated six odours (3 food and 3 cosmetic olfactory stimuli) on a visual continuous scale (VAS) on pleasantness, intensity, familiarity and edibility levels (from 0-“not pleasant/not perceived/not familiar/not edible” to 100-“extremely pleasant/strong/familiar/edible”) displayed on a computer. Then, they performed the first and second phase of the PIT test. After the two conditioning phases of the PIT, participants were asked to fill in the PANAS, the emotional and physiological questionnaire.

First phase of the PIT paradigm: Instrumental conditioning

We applied the procedure of the instrumental conditioning phase previously described in Chillà et al., (in prep.). Participants’ maximum grip force was measured before the experiment began. Then, during the first phase of the PIT test, participants learned that the energy invested in an instrumental action (press a hand grip) leaded to the delivery of odours. They correctly used the hand grip if they moved the mercury in the computerized thermometer up to the top and then down again for several times. They could smell a food or a cosmetic related odour in a random order (see procedure experiment 1-p. 57 for a complete description of the task).

Second phase of the PIT paradigm: Analog Pavlovian conditioning

In a second phase, we applied the procedure of the Pavlovian conditioning phase previously described in Chillà et al., (in prep.). Participants learned to associate odours with neutral images. The neutral image associated with the most pleasant food odour became the food positive conditioned stimulus (CS$_{food}$) and the other image associated with the most pleasant cosmetic related odour became the cosmetic positive conditioned stimulus (CS$_{cosmetic}$) (see procedure experiment 1-p. 58 for a complete description of the task).
Disgust condition
In the disgust condition, participants performed the disgust-priming task after the two learning phases, the PANAS, the emotional and physiological questionnaire.
Participants rated the pleasantness level of 35 standardized visual stimulus of disgust (from the DIsgust-RelaTed-Images (DIRTI) Database) while smelling an unpleasant fecal odour. Before the start of the priming test, participants smelled the faecal odour and evaluated the pleasantness and intensity level on a visual analogue scale from (0-‘‘not pleasant/not perceived’’ to 10-‘‘extremely pleasant/strong’’). Then, the priming disgust test started: participants had all the time to evaluate the pleasantness of each image. Mean of the total duration of the task was around 3 minutes. At the end of the priming task, participants filled in again the emotional and physiological questionnaire followed by the PANAS questionnaire to investigate if there was any effect of the disgust priming on emotions and physiological reactions (satiety, hunger, tiredness). Finally, participants were asked again to evaluate the pleasantness and intensity level of the faecal odour (after the priming test).

The transfer test began after the disgust priming. Participants had to press a handgrip to obtain an olfactory reward (cosmetic or food), as in the instrumental test, while the abstract images conditioned during the Pavlovian phase were presented. With this procedure, we tested the effect of the Pavlovian conditioned stimuli on the instrumental responding (transfer effect). The transfer test consisted on 12 trials identical to those in instrumental conditioning (two special 1s rewarded windows) followed by 12 trials administered under partial extinction (one special 1s window was rewarded) and 18 transfer test trials administered under extinction (no time window was rewarded). The presentation order of the three stimuli was randomized in the transfer test. There were two cycles of testing: in each series, each cue was presented three times consecutively, so that each Pavlovian stimulus was presented 2 times for a total of 18 transfer trials. Participants were free to respond or not respond on a voluntary basis according to their motivation.
After the PIT task, participants evaluated again the six odours on a continuous scale on pleasantness and intensity level to investigate if there were any effect of the experiment on the liking level of odours.

4 Fecal odor reconstitution was unpleasant and harmless at the concentrations used in this study.
No-disgust condition
In no-disgust condition, participants performed the neutral priming task after the two learning phases, the PANAS, the emotional and physiological questionnaire. Before the beginning of the priming test, participants smelled a mildly pleasant odour (galbex) and evaluated the pleasantness and intensity level on a visual analogue scale from (0-‘‘not pleasant/not perceived’’ to 10-‘‘extremely pleasant/strong’’). Further, participants rated the pleasantness level of 35 standardized neutral visual stimulus (from the DIsgust-RelaTed-Images-DIRTI Database) while smelling the mildly pleasant odour (galbex). As for priming disgust test, in the no-disgust task, participants had all the time to evaluate the pleasantness of each image. Mean of the total duration of the task was around 3 minutes. After this task, participants evaluated again the pleasantness and intensity level of the mildly pleasant odour. In addition, they filled in again the emotional and physiological questionnaire followed by the PANAS questionnaire to assess any effect of the neutral-priming on emotions and physical states.
Then, they performed the third phase (test phase) of the PIT experiment as the subjects in the disgust condition. After the PIT task, participants evaluated again the six odours on a continuous scale on pleasantness and intensity levels (see Table 6 for the procedure).
**Table 6**  
*The experimental design of the study*

<table>
<thead>
<tr>
<th>Instructions</th>
<th>Questionnaire</th>
<th>Odour evaluation</th>
<th>Instrumental</th>
<th>Pavlovian</th>
<th>Questionnaire</th>
<th>Priming task</th>
<th>Questionnaire</th>
<th>PIT</th>
<th>Odour evaluation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Participation agreement, PANAS, Demographica Emotional &amp; Physiological questionnaire, EAT-26</td>
<td>VAS evaluation of 6 odours</td>
<td>Selection of the most pleasant cosmetic and most pleasant food olfactory stimuli</td>
<td>Instrumental cond. (4 trials)</td>
<td>Pavlovian cond. (36 trials)</td>
<td>TEPS, PANAS, Emotional &amp; Physiological questionnaire, EAT-26</td>
<td>Disgust task: Faecal odour + disgust DIRTI images (35 pictures)</td>
<td>Neutral task: Galbex odour + neutral DIRTI images (35 pictures)</td>
<td>TEPS, PANAS, Emotional &amp; Physiological questionnaire, EAT-26</td>
<td>Transfer test (18 trials)</td>
</tr>
</tbody>
</table>

| 7 minutes | 8 minutes | 7 minutes | 12 minutes | 16 minutes | 8 minutes | 3 minutes | 8 minutes | 15 minutes | 7 minutes |

*Note.* First participants filled in the consent form, the demographical, TEPS, EAT-26, Emotional & physiological questionnaire and the PANAS. Second, participants performed an odour evaluation test on a computer screen. Two odours (the most pleasant cosmetic and the most pleasant food odours) were selected and used to perform the PIT test. The PIT task started with an instrumental conditioning training followed by a Pavlovian conditioning. Then, the participant in the disgust group performed the disgust priming task and the participant in the no-disgust group performed the neutral priming task. Finally, individuals performed the transfer test. The total duration of the experiment was around 90 minutes. In the figure, the time is given for each part of the experiment.
3.4.3 Results

A participant was included in the study if: 1) the difference in intensity between the cosmetic and food olfactory stimuli was inferior to 20, 2) the intensity scores of the two selected odours were above 40, 3) the computation of the Body Mass Index (BMI) was normal: the participants with a BMI > 30 (obese) and a BMI ≤ 16 (severely underweight) were excluded, 4) if individual had normal score in the EAT-26 test (no eating disorders risk).

In total, 5 subjects were excluded: 3 for the third criteria (1 subject was underweight, 2 subjects were overweight), 2 for technical problems, leaving 76 subjects (41 for the experimental condition and 35 for the control condition) for statistical analysis.

**Odour evaluation task before the PIT test**

For liking, a $2 \times 2$ (group: disgust, no-disgust) x 2 (odour: cosmetic, food) mixed repeated-measures analysis of variance (ANOVA) revealed no statistically significant difference between group and odour [$F(1, 74) = .06, p = .81, \eta^2 = .0008]$.

For intensity, a $2 \times 2$ (group: disgust, no-disgust) x 2 (odour: cosmetic, food) mixed repeated-measures analysis of variance (ANOVA) revealed no statistically significant difference between group and odour [$F(1, 74) = .01, p = .92, \eta^2 = .0001]$.

For familiarity, a $2 \times 2$ (group: disgust, no-disgust) x 2 (odour: cosmetic, food) mixed repeated-measures analysis of variance (ANOVA) revealed no statistically significant difference between group and odour [$F(1, 74) = 3.26, p = .08, \eta^2 = .04]$.

For edibility, a $2 \times 2$ (group: disgust, no-disgust) x 2 (odour: cosmetic, food) mixed repeated-measures analysis of variance (ANOVA) revealed no statistically significant difference between group and odour [$F(1, 74) = .25, p = .89, \eta^2 = .0003]$.
CHAPTER 3

EXPERIMENTAL PART

PIT test

*Instrumental conditioning*

A 4 (trial: 1, 2, 3, 4) x 2 (group: disgust, no-disgust) mixed repeated-measures analysis of variance (ANOVA) applied to the number of squeezes exceeding 50% of each participant’s maximal force did not show a significant effect of group \[ F(1, 74) = 2.21, p = .14, \eta^2 = .03 \], of trial \[ F(3, 220) = 1.19, p = .31 \] nor of the interaction between group and trial \[ F(3, 220) = .58, p = .66, \eta^2 = .007 \], revealing that after the training participants in both groups pressed sufficiently the hand grip to perform and obtain the olfactory stimuli (Figure 24).

Figure 24. Instrumental conditioning. Y-axis corresponded to number of squeezes and x-axis to the number of trials (1, 2, 3, 4).
Analog Pavlovian conditioning
Successful Pavlovian learning was assessed through reaction times (RTs) of the key-pressing task (Figure 25a) and a liking rating of the CSs (Figure 25b) indicators.

Reaction times (RT) indicator
A 3 (image: CS\textsubscript{food}, CS\textsubscript{cosmetic}, baseline) x 2 (group: disgust, no-disgust) mixed repeated-measures analysis of variance (ANOVA) was applied to reactions times. The mean of the RTs recorded on the first target of the on-task period of the key-pressing task was calculated for each Pavlovian stimulus. All responses that were more than 2 SDs from the mean (9% of the trials) or absent (0% of the trials) were removed.

No statistically significant effect of group \([F(1, 67) = .57, p = .45, \eta^2 = .008]\) of image \([F(2, 134) = 1.23, p = .30, \eta^2 = .02]\), nor interaction group, image in reaction time was observed \([F(2, 134) = .38, p = .69, \eta^2 = .005]\) (Figure 25a).

![Figure 25a](image)

**Figure 25a.** The reaction time (on first target) to detect the cue during the presentation of the Pavlovian stimuli for disgust and no-disgust group. Y-axis represented the reaction time to detect the Pavlovian stimuli. X-axis corresponded to Pavlovian stimuli (CS\textsubscript{food}, CS\textsubscript{cosmetic} and baseline). Error bars represented SEM.
CHAPTER 3

EXPERIMENTAL PART

Likability rating indicator

A 2 (image: CS_{food}, CS_{cosmetic}, baseline) x 2 (group: disgust, no-disgust) mixed repeated-measures analysis of variance (ANOVA) applied to the likability ratings revealed an effect of image, \[ F(2, 148) = 6.69, p \leq .001, \eta^2 = .08 \]. The image effect, showed a difference in the liking level for the three Pavlovian Stimuli. Post-hoc analysis revealing that CS_{cosmetic} (\( M = 70.97, SD = 17.83 \)) were rated significantly more pleasant compared to baseline (\( M = 59.41, SD = 23.55 \)), \[ t(75) = 3.59, p \leq .001, d = .55 \] and compared to CS_{food} (\( M = 59.12, SD = 28.82 \)), \[ t(75) = 3.35, p \leq .001, d = .50 \]. No statistical significant difference was found in the pleasantness rating between CS_{food} and baseline indicating that subjects did not prefer CS_{food} compared to baseline, \[ t(75) = 0.24, p = .81, d = .01 \], revealing that the Pavlovian conditioning worked only for CS_{cosmetic} (Figure 25b).

**Figure 25b.** The pleasantness rating of the Pavlovian stimuli after the Pavlovian conditioning phase. Y-axis represented the pleasantness rating for Pavlovian stimuli (CS_{food}, CS_{cosmetic} and baseline). X-axis corresponded to Pavlovian stimuli (CS_{food}, CS_{cosmetic} and baseline). Error bars represented SEM. *** \( p \leq .001 \).

**Priming tasks**

Before the transfer test and after the two learning tasks, participants performed one of the two priming tasks. Forty-one participants performed the disgust priming task (disgust condition) and thirty-
five participants performed the no-disgust priming task (no-disgust condition). The PANAS (Watson et al., 1988), and the following indicators were used to check the success of priming:

- Hungry level
- Disgust level
- Feeling “dirty”
- Feeling “to clean the hands”

The level of each indicator before and after disgust and no-disgust priming task was compared.

**PANAS Questionnaire**

A 2 (group: disgust, no-disgust) x 2 (condition: pre, post) x 2 (affect: positive, negative) mixed repeated-measures analysis of variance (ANOVA) showed a difference between disgust and no-disgust group from before and after the priming for the positive and negative affects [$F(1, 74) = 12.383, p = .00074, \eta^2 = .14$]. Post-hoc analysis showed that for disgust group positive affect scores were significantly lower after the disgust task ($M = 24.26, SD = 5.49$) than before ($M = 27.74, SD = 6.07$), [$t(40) = 4.98, p \leq .001, d = 0.60$]. Inversely, the negative affect score were higher after the disgust task ($M = 13.28, SD = 4.19$) than before ($M = 11.79, SD = 2.33$), [$t(40) = -2.16, p = .04, d = 0.44$] (Figure 26a, b).
Concerning no-disgust group, positive affect scores did not significantly change after the no-disgust priming task ($M = 27.36, SD = 6.63$) compared to before ($M = 28.07, SD = 7.25$), [$t(34) = 1.38, p = .17, d = 0.1$]. Negative affect scores did not significantly change after priming task ($M = 11.36, SD = 3.23$) compared to before ($M = 11.93, SD = 3.40$), [$t(34) = 1.57, p = .13, d = 0.17$] (Figure 27a, b).
**Figure 27a, b.** a) Positive affects scores (from PANAS questionnaire) b) and negative affects scores (from PANAS questionnaire) for no-disgust group before and after the disgust-priming task. Y-axis represented affects score and x-axis represented condition (before or after priming task). Error bars represented SEM.
Hunger level
A 2 (group: disgust, no-disgust) x 2 (condition: pre, post) mixed repeated-measures analysis of variance (ANOVA) showed a difference between disgust and no-disgust group from before and after the priming for hunger level \( [F(1, 74) = 8.36, p = .005, \eta^2 = 0.11] \). Concerning disgust group, hunger level was lower after the disgust task (\( M = 2.85, SD = 1.69 \)) than before (\( M = 4.43, SD = 2.15 \)), \( [t(40) = 6.22, p \leq .001, d = 0.82] \) (Figure 28).

![Figure 28](image)

**Figure 28.** The level of hunger, for disgust group before and after disgust-priming task. Y-axis corresponded to level of hunger and x-axis to condition (before and after priming task). Error bars represented SEM. *** p ≤ .001.

Concerning no-disgust group, hunger level was not significant different after neutral priming task (\( M = 4.16, SD = 2.63 \)), compared to before (\( M = 4.57, SD = 2.63 \)), \( [t(34) = 1.31, p = .20, d = 0.16] \).

Disgust level
A 2 (group: disgust, no-disgust) x 2 (condition: pre, post) mixed repeated-measures analysis of variance (ANOVA) showed a difference between disgust and no-disgust group from before and after the priming for disgust level \( [F(1, 74) = 35.5, p \leq .001, \eta^2 = 0.17] \). Concerning the disgust group, disgust level was higher after the disgust task (\( M = 4.64, SD = 2.74 \)), than before (\( M = 2.18, SD = 1.85 \)), \( [t(40) = -5.69, p \leq .001, d = 1.05] \) (Figure 29a).
Figure 29a. The level of disgust for disgust group before and after disgust-priming task. Y-axis corresponded to level of disgust and x-axis to condition (before and after priming task). Error bars represented SEM. *** $p \leq .001$.

Concerning no-disgust group, disgust level was significantly different before and after the neutral priming task, revealing a decreased of disgust level from before ($M = 2.44, SD = 1.83$), to after ($M = 1.59, SD = 0.93$), the priming task with the neutral odour, $[t(34) = 2.62, p \leq .01, d = 0.59]$ (Figure 29b).
Figure 29b. The level of disgust for no-disgust group before and after disgust-priming task. Y-axis represented level of disgust and x-axis condition (before and after priming test). Error bars represented SEM. ** $p \leq .01$.

Feeling to “clean the hands”

A 2 (group: disgust, no-disgust) x 2 (condition: pre, post) mixed repeated-measures analysis of variance (ANOVA) showed a difference between disgust and no-disgust group from before and after the priming for feeling to clean hands [$F(1, 74) = 18.52, p \leq .001, \eta^2 = 0.12$].

Concerning disgust group, feeling “to clean the hands” was higher after the disgust task ($M = 3.65$, $SD = 2.61$), than before ($M = 2.28$, $SD = 1.93$), [$t(40) = 4.31, p \leq .001, d = 0.60$] (Figure 30).
Figure 30. The level of feeling to “clean hands” for disgust group before and after disgust-priming task. Y-axis represented feeling “clean hands” and x-axis condition (before and after priming test). Error bars represented SEM. *** p ≤ .001.

Concerning no-disgust group, feeling “to clean the hands” was not significant different after the neutral task (M = 2.66, SD = 2.50), compared to before it (M = 3.03, SD = 2.68), [t(34) = 1.61, p = .12, d = 0.14].

Feeling “dirty”
A 2 (group: disgust, no-disgust) x 2 (condition: pre, post) mixed repeated-measures analysis of variance (ANOVA) showed a difference between disgust and no-disgust group from before and after the priming for feeling “dirty” [F(1, 74) = 4.5, p = .04, η² = 0.11].
Concerning disgust group, feeling “dirty” was higher after the disgust task (M = 2.79, SD = 2.16), than before (M = 1.55, SD = 0.76), [t(40) = -3.69, p ≤ .001, d = 0.77] (Figure 31).
Figure 31. The level of feeling “dirty” for disgust group before and after disgust-priming task. Y-axis represented feeling “dirty” and x-axis condition (before and after priming task). Error bars represented SEM. *** \( p \leq .001 \).

Concerning no-disgust group, feeling “dirty” was not significant different after the neutral task (\( M = 1.94, SD = 1.51 \)), compared to before it (\( M = 1.67, SD = 1.44 \)), [\( t(34) = -0.91, p = .37, d = 0.18 \)].
Transfer test
Effort mobilization was assessed by calculating two indicators:

1) Number of peak exceeding 50% of participant’s maximal force
2) Total force

1) Number of peak exceeding 50% of participant’s maximal force
A 2 (block: 1, 2) x 3 (image: CSfood, CScosmetic, baseline) x 3 (repetition: 1, 2, 3) x 2 (group: disgust, no-disgust) mixed repeated measured analysis of variance (ANOVA) showed a significant two-way interaction block and group, \([F(1, 74) = 7.3, p = .008, \eta^2 = .09]\), and two-way interaction repetition and group, \([F(2, 148) = 4.81, p = .009, \eta^2 = .06]\). No significant two-way interaction was observed between images and groups \([F(2, 148) = 0.55, p = .58, \eta^2 = .007]\). We found statistically significant Pavlovian conditioning for CScosmetic. Accordingly, we tested whether existed a specific transfer effect for CScosmetic between the two groups. Post-hoc analysis did not show any statistically difference in the number of squeezes for the CScosmetic between disgust \((M = 9.04, SD = 1.65)\) and no-disgust group \((M = 8.55, SD = 1.78)\), \([t(75) = 0.49, p = .62, d = .29]\).

Concerning, the two-way interaction block and group, revealed a difference in the number of squeezes between the two groups over time. Post-hoc analysis showed that the number of squeezes performed by disgust group tended to decrease from the first block \((M = 9.33, SD = 1.93)\) to the second block \((M = 8.10, SD = 2.08)\), \([t(40) = 1.78, p = .08, d = .31]\), indicating a slightly decline in the effort mobilized. Surprisingly, the number of squeezes performed by no-disgust group significantly increased from the first \((M = 8.79, SD = 2.03)\), to the second block \((M = 8.77, SD = 2.19)\), \([t(74) = -2.04, p = .05, d = .26]\), indicating an increase in the effort mobilized. No statistically significant difference was observed in the first block between disgust and no-disgust groups \([F(1,74) = 1.67, p = .19, \eta^2 = .07]\) or in the second block \([F(1,74) = 0.000322, p = .99, \eta^2 = .09]\) (Figure 32).
Concerning the two-way interaction between repetition and group, results showed that groups behaved differently across repetitions. Descriptive analyses showed that disgust group decreased the number of squeezes over time compared to no-disgust group that tended to increase the number of squeezes across repetitions. However, post hoc analysis reported no significant differences (all \( p > .20 \)).

2) *Total force*

A 2 (block: 1, 2) x 3 (image: CSfood, CScosmetic, baseline) x 3 (repetition: 1, 2, 3) x 2 (group: disgust, no-disgust) mixed repeated measures analysis of variance (ANOVA) showed a significant effect of block \( [F(1, 74) = 19.931, p \leq .001, \eta^2 = 0.21] \), indicating that the force decreased from the first to the second block. A marginal tendency for two-way interaction between block and group \( [F(1, 74) = 2.86, p = .09, \eta^2 = 0.03] \), revealing a difference use of the force across blocks between the two groups. Post-hoc analyses showed that the force used by disgust group decreased significantly from the first \( (M = 122.80, SD = 38.66) \) to the second block \( (M = 110.15, SD = 37.71) \), \( [t(75) = -20.58, p \leq .001, d = 0.18] \). A tendency to decline in the force was observed in no-disgust group
from the first ($M = 107.72, SD = 41.84$) to the second block ($M = 102.03, SD = 37.71$), [$t(75) = 40.82, p = .06, d = 0.18$] (Figure 33).

![Figure 33](image)

**Figure 33.** Total force in the first and in the second block for disgust and no-disgust group. Y-axis corresponded to total force and x-axis to number of block (1, 2). Error bars represented SEM. ***$p \leq .001$.

As for the number of squeezes indicator, we tested whether existed a specific transfer effect for CS$_{cosmetic}$ between the two groups according to Pavlovian conditioning results. Post-hoc analysis did not show any statistically difference in force for CS$_{cosmetic}$ between disgust ($M = 112.55, SD = 25.54$) and no-disgust group ($M = 106.35 SD = 27.64$), [$t(75) = 16, p = .69, d = .23$].

**Odour evaluation task after the PIT test**

For liking, a 2 (group: disgust, no-disgust) x 2 (odour: cosmetic, food) mixed repeated-measures analysis of variance (ANOVA) revealed no statistically significant difference between group and odour [$F(1, 74) =.41, p = .85, \eta^2 = .07$].

For intensity, a 2 (group: disgust, no-disgust) x 2 (odour: cosmetic, food) mixed repeated-measures analysis of variance (ANOVA) revealed no statistically significant difference between group and odour [$F(1, 74) = .014, p = .89, \eta^2 = .002$].
For familiarity, 2 (group: disgust, no-disgust) x 2 (odour: cosmetic, food) mixed repeated-measures analysis of variance (ANOVA) revealed no statistically significant difference between group and odour \[ F(1, 74) = 2.99, p = .14, \eta^2 = .05 \].

For edibility, a 2 (group: disgust, no-disgust) x 2 (odour: cosmetic, food) mixed repeated-measures analysis of variance (ANOVA) revealed no statistically significant difference between group and odour \[ F(1, 74) = .36, p = .92, \eta^2 = .004 \].

**Questionnaire**

1) *Correlation between the number of peak (exceeding 50% of participant’s maximal force) and the anticipatory subscale of TEPS questionnaire*

A Pearson product-moment correlation coefficient was performed to investigate the relationship between score to the anticipatory subscale of TEPS questionnaire and frequency of squeezes during the extinction phase of the transfer test. Analysis were performed on the mean of CS\textsubscript{food}, CS\textsubscript{cosmetic}, and baseline for the two blocks. For both groups, there were no statistically significant correlation between anticipatory score and the number of squeezes performed when CS\textsubscript{food} \[ r(75) = -.21, p = .58 \], CS\textsubscript{cosmetic} \[ r(75) = -.42, p = .45 \], or baseline \[ r(75) = -.58, p = .69 \] were at the screen.

2) *Correlation between the total force and the anticipatory subscale of TEPS questionnaire*

A Pearson product-moment correlation coefficient was computed to assess the relationship between the amount of total force during the extinction phase of the transfer test and the score to the anticipatory subscale of TEPS questionnaire. For both groups, there were no statistically significant correlation between the anticipatory score and the number of squeezes performed when CS\textsubscript{food} \[ r(74) = -.15, p = .44 \], CS\textsubscript{cosmetic} \[ r(74) = -.23, p = .47 \], or baseline \[ r(74) = -.69, p = .34 \] were at the screen.

3.4.4 Discussion

Based on literature and on experiment 1 and 2, we developed a study to test the sensitivity of the PIT paradigm to highlight “wanting” to obtain a relevant rewarded stimulus according to the
momentary individual’s goal. In particular, we tested if a previous situational disgust could putatively enhance disgust related cues salience and positively motivate a person to want cleansing products (such as “cosmetic olfactory stimuli) to cover potential environmental hazards and increase the appeal of physical cleansing. Two different categories of pleasant olfactory stimuli (cosmetic and food) were used and the individual’s goal manipulated to make cosmetic category more relevant compared to the other one. At the beginning of the task, the consummatory pleasure (liking) for the two pleasant odours was statistically similar. To manipulate the individual’s state, we performed a disgust priming task before the critical transfer phase of the PIT test where we tested the “wanting” for cosmetic and food olfactory stimulations. With this manipulation, we assumed to evoke participants’ physical disgust feeling and to make cosmetic olfactory stimuli highly relevant and rewarding. Three hypotheses were developed. Based on IST, disgust group, would had a higher “wanting” (effort mobilized) for relevant rewarded stimuli (CS\textsubscript{cosmetic}) compared to other category of rewarded stimuli (CS\textsubscript{food}) and baseline (no rewarded condition). No-disgust group, would mobilized a similar amount of effort for the two categories of rewarded olfactory stimuli, because it did not have specific needs to obtain one category of odour compared to the second one. Finally, we evaluated whether the individual trait dispositions in anticipatory experience of pleasure correlated with “wanting” response in the PIT test. As expected, when no specific goal was induced (as for participants in no-disgust group), a specific need to use differently the hand grip (by pressing more for CS\textsubscript{cosmetic}) was not observed. The two “wanting” indicators showed the same results: in no-disgust group, the “wanting” was similar for all the categories of olfactory stimuli. Concerning disgust group, results did not support our initial hypothesis. Despite the Pavlovian conditioning was demonstrated for cosmetic related cue and the disgust’s induction occurred, results did not show a higher “wanting” for the most relevant cosmetic odours. The two indicators of “wanting” showed that disgusted participants performed the same number of squeezes (first indicator) and mobilized the same amount of force (second indicator) for the three Pavlovian stimuli. In addition, the liking components seemed not to be affected. At the end of the PIT task, a liking rating performed on cosmetic and food odours revealed no statistically significant difference in pleasantness between cosmetic and food olfactory rewards. Several reasons may explain our results. First, the timing at which the disgust priming task was performed. The psychological impact of cleanliness/dirtiness is context sensitive. In this
experiment, we performed the PIT test *immediately after* the disgust induction. During this period of time, participants were still disgusted but did not have concretely anymore the “need” to cope with disgust feeling. It will be interested to investigate if doing the transfer test while a participant is being disgusted, may show an increase of “wanting” for cosmetic odours. Second, the intensity of the disgust induced by the priming task. Even if the questionnaires indicated that participants were more disgust compared to before performing the priming task, the induction may not be strong enough to develop an intensity level of disgust higher enough to induce the urge to obtain cleansing odours to cover the momentary physical disgust feeling. Third, the choice of the olfactory and visual disgust stimuli. The faecal reconstitution was at a standardized concentration: not too strong to induce vomit and not too low to not be perceived. This concentration was choose based on a pre-test on the disgust level induce by 3 different concentrations of the same faecal reconstitution. The concentration used in the study induced a medium-strong level of disgust. In addition, in order to increase the successful of our priming task, we decided to use visual disgust images associated with the malodour. We used the validated and standardized disgust images of the DIRTI database (Haberkamp et al., 2017). We can assume that concentration and images used were not powerful enough, to provoke specific increase of effort mobilized for $CS_{cosmetic}$. An alternative to our design would be to use PIT test with different concentration of faecal odour associated to DIRTI images.

However, we still found an effect of disgust on disgust group. Disgusted individuals disengaged more rapidly than no-disgusted individuals from the effort task in the transfer test. The first indicator (number of peak) highlighted a tendency to disengage that was supported by the second indicator (force) that reported a significantly decline of total force from the beginning to the end of transfer test phase. After the disgust priming task, disgust group reported an increase in negative affect, on disgust level, on feeling to “clean” hands and on feeling “dirty”. In parallel, participants in this group reported a decrease in hunger level (typically associated with disgust) and in positive affect. By inducing an increase of negative affect and decreased of positive affect, we could assume that disgust (at this intensity level) influences negatively the trend of the global effort mobilization during PIT task. Disgust individuals developed a general feeling of demotivation. The two “wanting” indicators showed the same results. Disgusted participants started to press the handgrip as no-disgusted participants. However, after some trials they decreased their effort in performing the task.
Concerning no-disgusted group, first indicator revealed a generalized increase of the number of squeezes from the beginning to the end of transfer test phase for all Pavlovian stimuli used during the Pavlovian conditioning phase. However, even if the number of squeezes increased from the first to the second block, no-disgusted group exerted the same amount of force over time (second indicator). By observing the results from no-disgusted group, we could assume that without any negative external inputs and in standardized experimental conditions, a participant was motivated to do the PIT task. Moreover, our results showed that when no personal need is induced, no statistically significant difference in “wanting” are observed for two pleasant olfactory rewards having similar reinforcing proprieties. Finally, we did not find a statistically significant correlation between the individual trait in anticipatory experience of pleasure and the two indicators of “wanting” response in the PIT test. Our results showed that individual trait to anticipate how pleasant or unpleasant something is going to be in the future was independent from “wanting” response in a PIT paradigm. The absence of correlation of these two measures suggested that expected pleasantness and “wanting” were two different concepts.

Conclusion

This experiment showed a negative influence of disgust on global effort mobilization trend, provoking a generalized decline of “wanting” during testing phase. However, findings did not show a sensitivity of PIT paradigm to highlight a specific “wanting” for cosmetic compared to food olfactory rewards after a disgust priming task. In addition, no correlation between the measure of expected pleasantness and “wanting” was found, revealing a potential independency of these two concepts from each other.
In the next experiment, we tested the sensitivity of PIT paradigm to highlight difference in “wanting” during a physiological state of hunger and of satiety. Accordingly, we manipulated the food reward’s salience by inducing a general satiety devaluation.

3.5 EXPERIMENT 4

Investigating the influence of subjective satiety level on learning phases and on instrumental to transfer effect in the Pavlovian to Instrumental Transfer (PIT) paradigm

Abstract

Incentive salience theory (IST) is a valuable framework through which food intake behaviours can be understood. Food intake is influenced by the incentive value of a food and by the hedonic preferences for it. The incentive value of a food is associated to the concept of wanting of IST and refers to appetite. Hedonic preferences are associated to the concept of liking of IST and correspond to palatability. According to incentive salience theory, effort mobilized by an organism, to obtain a reward or reward-associated cue, is modulated by his physiological state (e.g. satiety, thirsty, stress).

In this experiment, we wanted to advance food research field by investigating the sensitivity of Pavlovian to Instrumental transfer test (PIT) to highlight differences in effort mobilization in presence of two olfactory rewards (food and cosmetic) and altered physiological states. PIT procedure has largely been used in animal studies and recently applied to human. It provides a measure of effort engaged to obtain a reward (“wanting”) without asking explicitly the cognitive desire pushing participant to obtain it. The “wanting” measure is done outside and after consummatory phase (liking phase). Our findings showed that PIT paradigm was not sensitive enough to highlight difference between hunger and satiety group during Pavlovian conditioning for CS_{cosmetic} and CS_{food}. A transfer effect was observed for CSs compared to baseline (no reward associated) among all participants. The sensitivity of the measure was discussed.
3.5.1 Introduction

Incentive salience theory (IST) is a valuable framework through which food intake behaviours can be understood. Food intake is influenced by the incentive value of a food and by the hedonic preferences for it. The incentive value of a food is associated to the concept of wanting of the IST and refers to the appetite (i.e. the disposition to eat) (Berridge et al., 1996; Robinson & Berridge, 2000). Hedonic preferences are associated to the concept of liking of the IST and correspond to palatability (i.e. pleasure derived from eating a given food).

The first experiments that led to the development of the IST draw back to the nineties where Berridge and colleagues challenged the popular hedonic perspective of incentive motivational theories. Hedonic theories argued that the amount of effort mobilized by an organism to obtain a reward (motivation) was proportional to the pleasure experience during the consumption of this reward (Spence, 1956; Toates, 1998; Bindra, 1974; Bolles, 1972). The concept of pleasure was operationalized as the amount of effort mobilized by an organism to obtain a specific reward. For its part, however, the IST assumed that effort mobilized to obtain a reward was independent from pleasure experience during reward’s consumption. The pursuit of a reward depended on three components: wanting (motivation to obtain a reward), liking (pleasure felt during the consumption of it) and learning (automatic associations or cognitive representations of a reward) (Robinson & Berridge, 1998, Robinson & Berridge, 2003; Berridge & Kringelbach, 2008). Through experiments conducted on rodents, Berridge and co-workers proposed a different way to measure pleasure consisting of collecting prototypical orofacial expressions of rodents during food reward consumption (Berridge & Robinson, 1998; Mahler & Berridge, 2012; Peciña et al., 2003; Wyvell & Berridge, 2000, 2001). These orofacial expressions have been observed, later, in several other species (e.g. apes, rats, monkeys and human babies; Berridge, 2000). The mobilized effort after perception of a rewarding cue was considered, by Berridge, as an operationalization of the incentive motivation and could be measured separately from the concept of pleasure.

The specificity of IST, in the investigation of the reward process, is the consideration of the interaction between internal state of an organism in a specific moment, and environment. In particular, reward process is influenced by the interaction between organism’s physiological state (e.g. hunger/satiation, thirst, drug effects, stress) or brain state (e.g. changed in the dopamine level) and elements present in the environment (e.g. reward-associated cue) (Berridge & Doherty, 2014;
Pool et al., 2016). For example, a person is walking in the street in a hungry state (physiological state) and smells the odour of hamburger (reward-associated cue); in this instance, the person will probably have a peak of motivation for that food and will mobilized his resources to obtain it (food reward).

Animal studies showed the possibility to dissociate food “liking” from food “wanting” and highlighted the neural substrates underlie the expression of incentive salience and pleasure for food (for details see Peciña, Smith, & Berridge, 2006; Berridge, 2007; Berridge & Kringelbach, 2008; Berridge, 2009).

In framework of IST, many food scientists investigated the interaction between internal state and environment by manipulating participants’ satiety level (internal physiological state) (Finlayson, King, & Blundell, 2007a, 2007b; Finlayson et al., 2008; Lemmens et al., 2009; Epstein et al., 2003; Jiang et al., 2015). Several measures have been developed to assess food wanting and food liking. However, the debate on the usefulness of dissociating wanting from liking is still of major importance. For some authors, transparent methods (with good construct validity) are required to specific measure and discriminate food liking and wanting, because they are two separate psychological constructs (for a review see Finlayson & Dalton, 2012; see also Brondel, Landais, Romer, Holley, & Pénicaud, 2011; Brunstrom & Shakeshaft, 2009; Dai, Brendl, & Ariely, 2010; Epstein, Truesdale, Wojcik, Paluch, & Raynor, 2003; Finlayson, King, & Blundell, 2008; Goldstein et al., 2010; Havermans, Janssen, Giesen, Roefs, & Jansen, 2009; Kildegaard, Tønning, & Thybo, 2011; Lemmens et al., 2009; Morewedge, Huh, & Vosgerau, 2010; Olsen, Ritz, Hartvig, & Møller, 2011; Ouwehand & de Ridder, 2008; Tibboel et al., 2011; Türk Pereira, 2010; Veenstra & de Jong, 2010). Other authors defend the useless in dissociating these two components, because wanting and liking are dependent and co-vary during food intake in normal individuals (Havermans, 2011, 2012). According to those authors, it is not currently possible to objectively measure these components. New validated methods should be created to dissociate them in human.

In this article, we wanted to advance food research by investigating the sensitivity of Pavlovian to Instrumental transfer (PIT) method to highlight the differences in effort mobilization in presence of two rewards and altered physiological states. PIT procedure has largely been used in animal studies and recently applied to human (Talmi et al., 2008; Pool et al., 2014; Chillà et al., in prep.). It provides a measure of effort engaged to obtain a reward (“wanting”) without asking explicitly
the cognitive desire pushing the participant to obtain it. The “wanting” measure is done outside and after the consummatory phase (liking phase).

PIT procedure includes an instrumental, a Pavlovian conditioning and a test phase where influence of the Pavlovian conditioning on the instrumental action is tested (transfer effect). The instrumental phase consists for individual to learn that performing correctly an action gives a reward. The Pavlovian conditioning consists for subject to learn the association between a neutral stimulus with the absence or the presence of a reward (rewarding unconditioned stimulus, UCS). The final phase of the PIT paradigm consists in the test phase (transfer test), where Pavlovian stimuli (CS+ and CS-) are presented and influence on instrumental action is measured. In our experiment, transfer test was done under extinction (no reward was presented). This procedure allowed us to avoid any primary reinforcement caused by the presence of the reward. If the PIT effect took place, the CS+ presentation should induce an increase in action energization after its presentation.

In addition to this objective and in accordance with the previous experiments of this thesis, we aimed to exploratory investigate whether “wanting” correlated with expected pleasantness.

**Objectives**

In this experiment, we investigated the sensitivity of the PIT paradigm to measure “wanting” for food compared to cosmetic olfactory rewards during two physiological states: hunger and satiety. In particular, we wanted to investigate whether hunger and satiety states influenced differently learning phases of the PIT procedure and transfer effect during the critical testing phase. We manipulated food reward’s salience by changing the time at which participants ate and performed the PIT task. We created two groups: in one group participants were fed until satiety (satiety group). Through food devaluation, our objective was to decrease food related cues salience. In a second group, participants were food deprived (hunger group). Our goal was to increase food related cues salience.

To have same incentive value in testing phase as in learning phase, manipulation of satiety level was done before the instrumental and Pavlovian phases. In fact, according to Zhang (2009), "the incentive value of a cue will equal the learned value if and only if the physiological state during testing is similar to the state during learning." (Zhang et al., 2009, p. 2).
Several hypotheses were drawn for each phases of the PIT paradigm. Concerning instrumental phase, we assumed that the two groups pressed equally the handgrip to obtain olfactory rewards. In fact, the way to correctly use a tool (i.e. isometric hand grip) is normally related to psychological competences (such as for example QI) and not physiological states (such as hunger or satiety). Concerning Pavlovian conditioning, we assumed a more efficient conditioning for CS\textsubscript{food} than for CS\textsubscript{cosmetic} in hungry participants compared to satiated participants. This effect would be highlighted by means of two indicators: reaction times (RTs) to a key pressing task (performed during the Pavlovian training) and likability rating of the three Pavlovian stimuli (at the end of the Pavlovian training). For RTs, we assumed that hungry individuals should be faster in the pressing task when at the screen the images previously associated with the food olfactory rewards were presented compared to the images previously associated with cosmetic olfactory rewards due to food attentional bias effect. Same result was expected in satiated group (even if less strong), because literature showed that after a general satiety devaluation, the attentional bias for food cues is preserved (di Pellegrino et al., 2011). Concerning the post-liking test, hungry participants would rate more pleasant image previously associated with food olfactory rewards compared to the one associated with cosmetic olfactory rewards or baseline (no olfactory rewards associated) due to their physiological state and to food attentional bias effect (Loeber et al., 2013; Colagiuri & Lovibond, 2015; Watson et al., 2014; Corbit & Balleine, 2005; Colwill & Rescola, 1988; Delamater, 1996). Fed individuals would equally like the images associated with both olfactory rewards compared to the baseline, because in their physiological state, food olfactory rewards would not be more relevant compared to cosmetic olfactory rewards. Consequently, in transfer phase, satiety group, would perform for both olfactory rewards, the same number of squeezes and the same force. In fact, if participant was satiated, he would not have a physiological need to obtain food olfactory rewards and the two categories of rewards would acquire the same value. We did not assume a lower “wanting” for food olfactory rewards because literature showed that food associated cues could stimulate food consumption independently from the physiological satiety level of an organism (Weingarten, 1983; Reppucci et al., 2012). More specifically to PIT procedure, it has been observed that food-paired cues enhanced instrumental responding to obtain food even after a satiety devaluation phase (Watson et al., 2014).
Concerning hunger group in the transfer test, according to IST, we assumed that participants would continue to want food compared to cosmetic olfactory rewards, because food cues were more potent when you were hungry.

In addition to this first objective, we investigated whether it existed a relationship between expected pleasantness and “wanting” or whether these two concepts were independent. According to Pool and colleagues (2016), expected pleasantness referring to the expectations of how pleasant or unpleasant something is going to be in the future. The authors suggested that this concept differed from liking and wanting components. In this experiment, we wanted to exploratory investigate this suggestion. We measured expected pleasantness, by means of the Temporal Experience of Pleasure Scale (TEPS) (Gard et al., 2006), where individual trait to image a potential pleasurable event was measured and we correlated this score to “wanting” score. We assumed that if the two concepts were correlated, individuals having a higher score for expected pleasantness, would mobilize more effort in the PIT test. If the two concepts were not correlated, the expected pleasantness score did not co-vary with effort mobilization.

3.5.2 Method and Materials

Particpants. We invited 65 non-obese, non-dietary restrained individuals to participate to the experiment around lunch time. Participants were instructed not to eat or drink anything (apart from water) at least 15 hours before testing in order to have all subjects with a similar hunger level. The experiment was run in the Brain and Behavioural Laboratory of the University of Geneva (BBL). The experiment was approved by the FPSE ethical committee of the University of Geneva.

Visual stimuli. We selected 4 abstract figures from an initial set of 33 figures that have been evaluated by 34 participants ($M_{age} = 27.7$, $SD_{age} = 2.97$) on a 9-point Likert pleasantness scale (from 0-not pleasant, to 9-extremely pleasant) as equally neutral (not pleasant/not unpleasant). Three were used in the Pavlovian phase, one in the instrumental phase (see experiment 1, chapter visual stimuli for more details).

Olfactory stimuli. We selected 3 food and 3 cosmetic olfactory stimuli from an initial set of 25 odours that have been evaluated by 30 participants ($M = 28.6$, $SD = 5.66$) on intensity, pleasantness, edibility and familiarity on a 10-point Likert scale (from 0-“not pleasant/not intense/not
familiar/not edible at all” to 10- “extremely pleasant/intense/familiar/edible”) (Table 7).

Table 7
*The odours used in study*

<table>
<thead>
<tr>
<th>Odours</th>
<th>Concentration (ml/l)</th>
<th>Dipropylene glycol (ml/l)</th>
<th>Mean Pleasantness (SD)</th>
<th>Mean Intensity (SD)</th>
<th>Mean Familiarity (SD)</th>
<th>Mean Edibility (SD)</th>
<th>Category odour</th>
</tr>
</thead>
<tbody>
<tr>
<td>Butter</td>
<td>5</td>
<td>5</td>
<td>8.01 (±2.54)</td>
<td>7.02 (± 2.03)</td>
<td>8.20 (±2.30)</td>
<td>9.25 (±2.55)</td>
<td>Food odour</td>
</tr>
<tr>
<td>Popcorn</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Strawberry</td>
<td>2</td>
<td>8</td>
<td>7.49 (±1.99)</td>
<td>8.05 (±1.54)</td>
<td>8.50 (±2.12)</td>
<td>9.23 (±1.27)</td>
<td>Food odour</td>
</tr>
<tr>
<td>Melt chocolate</td>
<td>2</td>
<td>8</td>
<td>8.42 (±2.02)</td>
<td>8.89 (±2.01)</td>
<td>8.98 (±2.08)</td>
<td>9.68 (±2.37)</td>
<td>Food odour</td>
</tr>
<tr>
<td>Ariana</td>
<td>5</td>
<td>5</td>
<td>7.53 (±2.65)</td>
<td>7.45 (±2.68)</td>
<td>8.75 (±2.14)</td>
<td>2.10 (±1.25)</td>
<td>Cosmetic odour</td>
</tr>
<tr>
<td>Aladinate</td>
<td>5</td>
<td>5</td>
<td>7.68 (±2.41)</td>
<td>7.52 (±2.33)</td>
<td>7.58 (±2.12)</td>
<td>3.15 (±1.02)</td>
<td>Cosmetic odour</td>
</tr>
<tr>
<td>Muguet</td>
<td>5</td>
<td>5</td>
<td>7.99 (±2.63)</td>
<td>7.01 (±2.58)</td>
<td>8.04 (±2.47)</td>
<td>3.48 (±0.98)</td>
<td>Cosmetic odour</td>
</tr>
<tr>
<td>Empty</td>
<td>-</td>
<td>10</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>No odour</td>
</tr>
</tbody>
</table>

*Note.* The essences were provided by Firmenich, S.A., Geneva, Switzerland. The essences were dissolved in propylene glycol.

*Instrumental apparatus.* An isometric handgrip dynamometer (TDS121C) was used to measure the effort mobilized (“wanting”) to obtain food and cosmetic stimuli. The dynamometer was connected to the MP150 Biopac Systems (Santa Barbara, CA) and recorded (sampling rate 30Hz) using MATLAB (version 8.0). The participants received a visual online feedback concerning the force they exerted on the handgrip (Psychtoolbox 3.0). This feedback consisted of an image of a thermometer displayed on the left side of the screen (30° visual angle). The “mercury” of this thermometer-like image moved up and down according to the mobilized effort exerted by the participant. The “mercury” reached the top of the scale if the handgrip was squeezed with at least
50 % or 70 % of the maximal force of the participant (randomly chosen for each strength data point).

**Questionnaires.** The following questionnaires were used in the experiment: 1) Consent form 2) Demographic questionnaire, 3) Eating Attitudes Test (EAT-26; Garner, 1982), 4) Temporal Experience of Pleasure Scale (TEPS; Favrod et al., 2008), 5) Hunger rating scale.

We collected participant’s general information (such as age, sex, body mass index) by means demographic questionnaire. We used the Eating Attitudes Test to assess eating disorder risk. It was a self-report questionnaire with 26-item measuring symptoms and concerns characteristic of eating disorders. We used the French version of the Temporal Experience of Pleasure Scale to evaluate individual traits in anticipatory and consummatory experiences of pleasure. The French version of the Temporal Experience of Pleasure Scale included two 6-point Likert scales (from 1-“very false for me” to 6-“very true for me”) measuring distinct constructs: the anticipatory and the consummatory scale. Specifically, the first scale was related to reward responsiveness and imagery, and the second scale was related to openness to different experiences, and appreciation of positive stimuli. Hunger level was assessed through a visual analogue scale (VAS) (from 1-“not hungry at all” to 10-“very hungry”).

**Procedure**

*For both conditions*

Participation required the completion of a consent form, and of the other questionnaires (Table 8).

Each participant evaluated the level of hunger on a visual analogue scale (from 0-“not hungry at all” to 10-“very hungry”). Thirty participants were assigned to satiety condition if their level of hunger was equal or inferior to 6 and thirty to hunger condition if their level of hunger was equal or superior to 7. Later, each subject rated on a continuous scale the pleasantness, intensity and familiarity and edibility (from 0-“not pleasant/not intense/not familiar/not edible at all”, to 100-“very pleasant/very intense/very familiar/very edible”) level of six odours by means of a cannula delivering the odours directly in the nostrils. Each odour was presented once during 2s using a computer controlled olfactometer (airflow 1 L/min) that delivers the olfactory stimulation rapidly, without thermal and tactile confounds via a nasal cannula (as used in Ischer et al., 2014, Pool et al. 2014 and Chillà et al., in prep.). For each subject, the most pleasant food and the most pleasant
cosmetic odours were used as rewards during PIT paradigm. Importantly, the two olfactory rewards had similar level of intensity. The duration of the experiment was of 2 hours. Students received credits for their participation.

**Menu**

Participants could choose between 1) a cheese, ham or vegetarian (salad and cucumber) sandwich. If the participant was gluten allergic, he could choose a salad with cheese, ham and cucumber. If it was milk allergic the menu was delivered without cheese. The participant could have one or two sandwiches, in order to attend his subjective level of satiety. 2) a fruit: banana, apple 3) a glass of water. With this procedure, we could know exactly what the participant chose to eat. The menu was served in the kitchen room of the Brain and Behavioral Laboratory of the University of Geneva (BBL) (Figure 34).

![Menu of the experiment](image)

**Figure 34.** Menu of the experiment. The participants could choice between a sandwich or salads served with a glass of water and a fruit.

**Satiety condition**

Before PIT task, participant ate a full meal until satiety. After eating the meal, participant evaluated his level of hunger on a visual analogue scale. The PIT task then started. During the first phase of the PIT test, participant learned that the energy invested in an instrumental action (press a hand grip) leaded to the delivery of olfactory rewards. In a second phase, participant associated the olfactory rewards with neutral images. In third test phase, participant executed again instrumental

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5The ingredients for the menu were bought at supermarket at the same morning of the experiment. The sandwiches and the salads were then prepared by the experimenter before each experiment. The general hygiene standards of a meal preparation were applied here (washing hands, using clean knife and glass, using different cutting board for ham, vegetables and cheese ingredients).
action, while they were viewing the neutral images previously associated with the olfactory rewards. After the PIT task, participant evaluated again the olfactory rewards on a continuous scale on pleasantness, intensity, familiarity and edibility levels.

**Hunger condition**

Participants in this condition started directly the PIT task. The PIT procedure was the same as for satiety condition. At the end of the PIT test, participant was asked again to evaluate their level of hunger and the pleasantness, intensity, familiarity and edibility levels of the olfactory rewards (from 0-“not hungry/pleasant/intense/familiar/edible” at all to 10-“very hungry/pleasant/intense/familiar/edible”). After completed the PIT paradigm, participant was welcome to eat a full meal until satiety.

**PIT Paradigm**

The procedure used in Chillà et al., (in prep.) has been replicated in this study (Table 8).

PIT test was divided in 3 sub-phases: instrumental, Pavlovian and transfer phases. Briefly, in the instrumental phase, individual learned that performing correctly an instrumental action enhanced obtaining pleasant olfactory stimuli. In the Pavlovian phase, participant learned to associate neutral images with olfactory rewards (food and cosmetic). During the transfer phase, participant had to press a handgrip to obtain an olfactory reward (food and cosmetic), as in the instrumental test, while the abstract images conditioned during the Pavlovian phase were presented. Critically, in this transfer phase, participant did not receive the reward. With this procedure, we tested the effect of the Pavlovian conditioned stimuli on the instrumental responding (transfer effect). Participant was free to respond or not respond on a voluntary basis according to his motivation.
Table 8
The experimental design of the study

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Note. First participant filled in the consent form, the demographical, TEPS, EAT-26, emotional & physiological questionnaire and the PANAS. Second, participant performed an odour evaluation test on a computer screen. Two odours (the most pleasant food and the most pleasant cosmetic odours) were selected and used to perform the PIT test. Then, participant in satiety group ate a meal to satiety compared to participant in hunger group that ate the meal after the PIT test. The PIT task started with an instrumental, followed by a conditioning training and finally by the transfer test. Then, the participant evaluated again the odours. The total duration of the experiment was around 120 minutes. In the figure, the time is given for each part of the experiment.
3.5.3 Results
A participant was included in the study if: 1) he had hedonic level for the six olfactory stimuli used in the odour evaluation task that was higher than 60, 2) the difference in intensity between the food and cosmetic odours was inferior to 20, 3) the intensity scores of the odours were above 40, 4) the computation of the Body Mass Index (BMI) was normal: the participants with a BMI > 30 (obese) and a BMI ≤ 18.5 (underweight) were excluded, 5) if he had normal score in the EAT-26 test.

In total, 4 subjects were excluded: 1 for the first criteria, 2 for the fourth criteria, and 1 for technical problems, leaving 61 subjects (27 for the hunger group and 34 for the satiety group) for the statistical analysis.

The following pre-conditions have been checked to ensure that all participants started the experiment in the same olfactory conditions and to ensure the effect of the manipulation of hunger: 1) at the arrival at the laboratory, liking for food olfactory rewards should be higher compared the liking for cosmetic olfactory rewards among participants. 2) In satiety group, after meal consumption, the level of hunger statistically decreased from before and after meal consumption served until satiety.

Pre-condition number 1
Overall: At the arrival at the laboratory
For liking, a $2 \times 2$ (group: disgust, no-disgust) x 2 (odour: cosmetic, food) mixed repeated-measures analysis of variance (ANOVA) revealed a significant effect of type of odour on liking [$F(1, 59) = 19.16, p \leq .001, \eta^2 = .25$] (Figure 35), but no statistically significant interaction between group and odour [$F(1, 59) = 1.69, p = .19, \eta^2 = .03$].

For intensity, a $2 \times 2$ (group: disgust, no-disgust) x 2 (odour: cosmetic, food) mixed repeated-measures analysis of variance (ANOVA) revealed no statistically significant difference between group and odour [$F(1, 74) = .011, p = .92, \eta^2 = .0001$].

For familiarity, a $2 \times 2$ (group: disgust, no-disgust) x 2 (odour: cosmetic, food) mixed repeated-measures analysis of variance (ANOVA) revealed no statistically significant difference between group and odour [$F(1, 74) = 3.26, p = .08, \eta^2 = .04$].

For edibility, a $2 \times 2$ (group: disgust, no-disgust) x 2 (odour: cosmetic, food) mixed repeated-measures analysis of variance (ANOVA) revealed no statistically significant difference between group and odour [$F(1, 74) = .25, p = .89, \eta^2 = .0003$].
Figure 35. Pleasantness rating of food and cosmetic odours for participants at the laboratory’s arrival. Y-axis represented pleasantness rating and x-axis the category of odour (food and cosmetic). Error bars represented SEM. *** $p \leq .001$.

Pre-condition number 2

Hunger level after meal’s consumption: satiety group

Concerning satiety group, paired $t$ tests revealed that the level of hunger was statistically lower after meal consumption ($M = 0.50$, $SD = 0.71$) compared to the hunger level before meal consumption ($M = 4.32$, $SD = 1.17$) [$t(33) = 16.41$, $p \leq .001$, $d = 3.95$] (Figure 36).
Figure 36. Level of hunger for satiety group before and after meal consumption. Y-axis corresponded to hunger level and x-axis to the condition in which participant was during the assessment of hunger level (before or after meal consumption). Error bars represented SEM. *** $p \leq .001$.

In addition, mean level of hunger for hunger group was statistically higher before meal consumption ($M = 7.6$, $SD = 0.75$) compared to after meal consumption ($M = 0.85$, $SD = 1.1$), $[t(26) = 26.3$, $p \leq .001, d = 7.17]$.

Evaluation of odours used in PIT task
The evaluations were the same as the evaluation performed at the laboratory’s arrival (see pre-condition number 1 for detail). No statistically significant difference between odours and groups was observed ($ps > .19$). The main statistically difference concerned the pleasantness for odours, revealing that food were more liked compared to cosmetic odours $[F(1, 59) = 19.16, p \leq .001, \eta^2 = .25]$.

PIT paradigm

Instrumental conditioning
satiety group VS. hunger group
A 4 (trial:1, 2, 3, 4) x 2 (group: hunger, satiety) mixed repeated-measures analysis of variance (ANOVA) applied to the number of squeezes exceeding 50% of each participant’s maximal force over 4 trials showed a significant effect of group, $[F(1, 59) = 7.5, p = .008, \eta^2 = .22]$, indicating
that hungry participants performed more squeezes compared to satiated subjects. More important for our hypothesis, no statistically significant difference was found for the interaction between trial and group [$F(3, 177) = .29, p = .83, \eta^2 = .24$], revealing that the two groups pressed similarly and sufficiently to perform the task after a short training phase (Figure 37).

![Figure 37](image)

**Figure 37.** Instrumental conditioning of hunger and satiety group. Y-axis represented number of squeezes and x-axis the number of trials.

**Analog Pavlovian conditioning**

To assess successful Pavlovian contingency learning, two measures were performed: the reaction times (RTs) of the key-pressing task (Figure 38a) and the likability rating of the CSs (Figure 38b) indicators.

**Reaction time (RTs) indicator**

We analysed RTs on the first target of the on-task period. All responses that were more than 2 SDs from the mean (1% of the trials) or absent (0% of the trials) were removed. A 2 (image: CS\textsubscript{food}, CS\textsubscript{cosmetic}) x 2 (group: hunger, satiety) mixed repeated-measures analysis of variance (ANOVA)
was applied to reaction times (RTs) and showed no effect of images on groups \( [F(1, 59) = 1.29, p = .26, \eta^2 = .05] \). We found a tendency for image’s effect \( [F(1, 59) = 3.2, p = .08, \eta^2 = .05] \). Post-hoc analysis on image effect showed that RTs to the target were higher when the image presented to the screen was the one previously associated with the food olfactory rewards \( (M = 403.08, SD = 70.83) \) compared to the image associated with the cosmetic olfactory rewards \( (M = 389.19, SD = 66.63) \) for both groups: \( [t(55) = 2.06, p = .05, d = 0.20] \) (Figure 38a).

Figure 38a. The y-axis corresponded to reaction time (ms) to detect the cue during the presentation of CS\textsubscript{food} and CS\textsubscript{cosmetic} for both groups. The x-axis corresponded to the Pavlovian stimuli (CS\textsubscript{food}, CS\textsubscript{cosmetic}). Error bars represented ed SEM. * \( p \leq .05 \).

Likability rating indicator
3 (image: CS\textsubscript{food}, CS\textsubscript{cosmetic}, and baseline) x 2 (group: hunger, satiety) mixed repeated-measures analysis of variance (ANOVA) applied to the likability ratings of the three Pavlovian images did not revealed a statistically significant interaction between images and groups. Participants in both groups, evaluated similarly the three Pavlovian images \( [F(2, 118) = 1.4901, p = .23, \eta^2 = 0.02] \) (Figure 38b). No effect of image was found \( [F(2, 118) = 0.27, p = .76, \eta^2 = 0.005] \).
According to reaction time and likability indicators, no differences were observed in the two groups in the conditioning of CSfood and CScosmetic, meaning that the basic of the experiment was not achieved. According to the absence of difference between groups on Pavlovian conditioning, transfer test analysis was conducted on all the participants without distinguishing hungry and satiated individuals.

Transfer test

Effort mobilization was assessed by calculating two indicators:

1) Number of peak exceeding 50% of participant’s maximal force
2) Total force

1) Number of peak exceeding 50% of participant’s maximal force

We calculated the number of squeezes exceeding 50% of participant’s maximal force to assess the effort mobilized to obtain a reward (Talmi et al., 2008; Pool et al., 2014). A 2 (block: 1, 2) x 3 (image: CSfood, CScosmetic, and baseline) x 3 (repetition: 1, 2, 3) repeated-measures analysis of variance (ANOVA) showed a statistical significant effect of image [$F(2, 120) = 4.36, p = .01, \eta^2 = 0.07$]. The significant main effect of image revealed that all the participants pressed more for the
CSs compared to the baseline (Figure 40). Post-hoc analysis showed that subjects pressed less for baseline (\(M = 9.59, SD = 5.61\)) compared to CS\(_{food}\) (\(M = 10.40, SD = 6.01\)), \([t(60) = 2.66, p = .01, d = 0.14] \) and CS\(_{cosmetic}\) (\(M = 10.48, SD = 5.84\)), \([t(60) = 2.57, p = .01, d = 0.15]\). No statistical significant difference was found between the number of squeezes performed for CS\(_{food}\) or CS\(_{cosmetic}\), \([t(60) = 0.23, p = .82, d = 0.01]\) (Figure 40).

**Figure 40.** Number of squeezes performed by participants for the three Pavlovian stimuli during the extinction phase of the transfer test. Y-axis represented the number of squeezes and x-axis the type of Pavlovian stimuli (CS\(_{food}\), CS\(_{cosmetic}\) and baseline). Error bars represented SEM. **\(p \leq .01\).**
Total force

A 2 (block: 1, 2) x 3 (image: CS_food, CS_cosmetic, baseline) x 3 (repetition: 1, 2, 3) repeated-measures analysis of variance (ANOVA) showed a significant effect of block \[F(1, 60) = 27.34, p \leq .001, \eta^2 = 0.3\] (Figure 41), of image \[F(2, 120) = 4.66, p = .01, \eta^2 = 0.07\] (Figure 42), and of repetition \[F (2, 120) = 3.40, p = .04, \eta^2 = 0.09\] (Figure 43). The block effect showed that total amount of force decreased significantly from the first \((M = 99.65, SD = 9.19)\) to the second block \((M = 90.74, SD = 10.92)\) (Figure 41).

**Figure 41.** The force exerted by the participants during the first and the second block. Y-axis corresponded to total force and x-axis corresponded to the number of block (1 and 2). Error bars represented SEM. ***\(p \leq .001\).

The image’s effect showed a significant difference in the total amount of force used for CSs compared to baseline. Post-hoc analysis revealed that force was higher for CS_food \((M = 97.03, SD = 34.33)\), compared to baseline \((M = 91.00, SD = 33.42)\), \[t(60) = 3.03, p = .003, d = 0.18\] and for CS_cosmetic \((M = 97.55, SD = 30.86)\), compared to baseline \[t(60) = 2.56, p = .01, d = 0.20\]. There was not a statistical significant difference in the total amount of force for CS_food and CS_cosmetic, \[t(60) = -0.20, p = .84, d = 0.02\] (Figure 42).
Concerning the effect of repetition, statistically significant difference was observed between the first ($M = 97.14$, $SD = 31.55$) and the third repetition, revealing a significant decline of the force from the beginning to the end of the experiment ($M = 93.59$, $SD = 35.47$) [$t(60) = 1.65$, $p = .01$, $d = 0.11$] (Figure 43). No difference was observed between the first to the second repetition ($M = 94.85$, $SD = 33.42$) [$t(60) = 1.65$, $p = .11$, $d = 0.07$] or between the second and the third repetition [$t(60) = -2.52$, $p = .01$, $d = 0.04$].
Pleasantness level of olfactory rewards

Satiety group

There were no statistically significant difference between the mean pleasantness of food ($M = 65.35$, $SD = 7.98$) and the mean pleasantness of cosmetic olfactory rewards ($M = 62.04$, $SD = 8.02$), for satiety group, after meal consumption, [$t(33) = 2.19$, $p = .68$, $d = .47$], revealing that satiation devaluation decreased the liking level for food compared to cosmetic odours. No statistical significant difference was observed for the mean intensity of food ($M = 65.25$, $SD = 8.89$) compared to the mean intensity of cosmetic odours ($M = 64.87$, $SD = 9.25$), [$t(60) = -1.34$, $p = .58$, $d = .42$]. No statistically significant difference was observed for the mean familiarity of food ($M = 78.85$, $SD = 8.41$) compared to the mean familiarity of cosmetic olfactory rewards ($M = 80.45$, $SD = 9.21$) [$t(60) = 6.22$, $p = .87$, $d = .12$]. There was a significant difference for the mean edibility of food ($M = 80.11$, $SD = 16.85$) compared to the mean edibility of cosmetic olfactory stimuli ($M = 52.25$, $SD = 10.41$), [$t(33) = 1.2$, $p \leq 0.001$, $d = 1.99$].

Questionnaire data

1) Correlation between the number of peak (exceeding 50% of participant’s maximal force) and the anticipatory subscale of TEPS questionnaire

A Pearson product-moment correlation coefficient was performed to investigate the relationship between score at the anticipatory subscale of the TEPS questionnaire and frequency of squeezes during the extinction phase of the transfer test. Analysis were performed on the mean of CS<sub>food</sub>, CS<sub>cosmetic</sub>, and baseline for the two blocks. For both groups, there were no statistically significant correlation between the anticipatory score and the number of squeezes performed when CS<sub>food</sub> [r(59) = - .45, $p = .44$], CS<sub>cosmetic</sub> [r(59) = - .14, $p = .74$], or baseline [r(59) = - .52, $p = .69$], were at the screen.

2) Correlation between the total force and the anticipatory subscale of TEPS questionnaire

A Pearson product-moment correlation coefficient was computed to assess the relationship between the amount of total force during the extinction phase of the transfer test and the anticipatory score of the TEPS questionnaire. For both groups, there were no statistically significant correlation between the anticipatory score and the number of squeezes performed when CS<sub>food</sub> [r(59) = -.17, $p = .82$], CS<sub>cosmetic</sub> [r(59) = - .11, $p = .84$], or baseline were at the screen [r(59) = -.48, $p = .25$].
3.5.4 Discussion

In this study, we had two objectives: 1) to investigate whether the manipulation of subjective physiological state of satiety affected the learning phases and the transfer effect of the PIT paradigm 2) to exploratory investigate whether expected pleasantness correlated with “wanting” measure.

Participants arrived at the laboratory in a fasting state (no eating or drinking sweet liquids 15h before the experiment). We, then, manipulated the food olfactory reward’s salience by changing the time at which participants ate and performed the PIT task. More specifically, we created two main groups: hunger and satiety groups. The subjects in satiety group ate the meal before performing the PIT task while the subjects in hunger group performed the experiment in a fasting state (the meal was given after the PIT test).

Before performing the PIT task, two conditions were assessed to ensure that all participants started the experiment in the same olfactory conditions and to ensure the manipulation effect on hunger level. The first condition consisted to evaluate that at the laboratory’s arrival, liking and intensity levels of the two olfactory rewards (food and cosmetic) were similar among participants. The second condition consisted to evaluate in satiety group that the level of hunger decreased from fasting to satiety state. Both conditions were successfully filled in before beginning the PIT test.

The effect of physiological state on PIT learnings phases was assessed during the instrumental and the Pavlovian phases. The effect of physiological manipulation on transfer effect was supposed to be tested during the critical phase of the PIT paradigm. We assumed no influence of the physiological state (hunger/satiety) on the instrumental learning phase. In fact, the way to correctly press the tool normally is related to psychological competences (such as QI) and not to physiological state (such as hunger or satiety). Thus, in the instrumental phase, we assumed that fed and deprived individuals would press similarly and sufficiently the handgrip to obtain rewards. Our findings supported our hypothesis: subjects pressed similarly the handgrip to obtain the olfactory rewards after a short training.

Concerning the Pavlovian conditioning, we used two parameters to evaluate the success of the Pavlovian conditioning phase: the RTs and the likability rating. Concerning the RTs, we assumed that hungry individuals would be faster to detect the asterisk when CS_{food} was at the screen due to the attentional bias for food cues. In addition, hungry individuals would rate more pleasant the images associated with CS_{food} compared to the others associated with CS_{cosmetic}, since hungry individuals had a physiological need for food rewards and hunger increase the palatability for food (Spiegel, 1989; Pelchat et al., 2004). According to di Pellegrino et al. (2011), even if satiation devaluation occurs, visual selective attention to valued food does not change. Thus, we assumed that satiated individuals
would be faster in detecting the asterisk when $CS_{food}$ was at the screen compared to the $CS_{cosmetic}$. Additionally, satiated individuals would rate equally the pleasantness of the two CSs, because they did not have a physiological need for food rewards.

Concerning the reaction time indicator, results showed that individuals were faster in detecting the asterisk when $CS_{cosmetic}$ was at the screen compared to when $CS_{food}$ was displayed at the screen. However, we could not conclude whether the Pavlovian conditioning occurred based on the reaction time indicator, because we did not have a baseline (a neutral image without any odour associated) to compare the reaction time for $CS_{cosmetic}$ and for $CS_{food}$.

Concerning the second indicator (liking rating), no statistically significant difference was found for the three Pavlovian stimuli among hunger and satiety groups. The no statistically significant difference between hunger and satiety group during Pavlovian conditioning, could be explained by multiple factors such as the level of hunger or the olfactory rewards. Despite, the hunger level scale showed a mean moderate-high level of hunger for this group (7.6 points on 10 points on VAS), we could assume that the intensity of hunger was not strong enough to provoke a physiological need for food related items. Consequently, no statistically significant difference in liking between $CS_{food}$ and $CS_{cosmetic}$ was observed for hungry individuals. Further research should consider increasing the amount of food deprivation hours to induce a higher hunger level and potentially a higher need for food category.

Another potential reason behind the no statistically significant difference in liking between $CS_{food}$ and $CS_{cosmetic}$ in hungry individuals could be related to the use of real olfactory stimuli during the study. Participants concretely consumed the rewards by smelling them during the Pavlovian conditioning phase and the entire initial part of the transfer test. This consumption could potentially decrease the hunger level and consequently the participant’s pleasantness of food olfactory rewards. It will be interesting to compare differences in liking by replicating the same design but using winning’s points or symbolic images of food rewards during the Pavlovian phase and to give the opportunity to consume food rewards only at the end of the task.

The absence of statistically significant differences between $CS_{food}$ and $CS_{cosmetic}$ for hungry individuals in the likability test of the Pavlovian phase did not allow us to check the effect of Pavlovian cues on instrumental action (transfer effect) for each group. Accordingly, we decided to test the transfer effect on the whole sample instead of testing it in each group separately. In other words, we did not take into account the physiological state during the transfer test.

Concerning the transfer test, participants performed more squeezes for CSs compared to baseline. However, no statistically significant difference was observed between $CS_{food}$ and $CS_{cosmetic}$.

Moreover, concerning the force’s indicator, a decrease in “wanting” along the time was observed. In addition, force’s indicator showed a higher force used for CSs compared to baseline. This indicator
supported our first indicator by highlighting a transfer effect for CSs compared to baseline, revealing a higher reward-cue “wanting” compared to no reward condition (baseline).

Concerning the liking level for satiety group, after PIT, there were no statistically significant difference between mean pleasantness of food and cosmetic olfactory rewards. This result filled our hypothesis that devaluation of food cue through satiation decreased the liking for food category.

Concerning liking level for hunger group, surprisingly after the PIT test there were no statistically significant difference anymore between mean pleasantness of food and cosmetic olfactory rewards (compared to the beginning of the experiment where differences revealed that for hungry participants food olfactory rewards were more pleasant). However, this result can be due to the use of real olfactory stimuli during the study. Participants concretely consumed the rewards by smelling them during Pavlovian conditioning phase and entire initial part of transfer test. This consumption could potentially decrease hunger level and consequently liking for food olfactory rewards by bringing their level to the one of cosmetic rewards at the end of the experiment. As such, the use of real food olfactory rewards could be a limitation to the study. It will be interesting to see if giving only points to win olfactory rewards during the Pavlovian phase could increase the participant’s willingness to obtain more food rewards during the extinction phase of transfer test and liking ratings for food rewards at the end of the study.

In addition, we measured hunger level only at the beginning of the study and after meal consumption. It would be interested to incorporate a hunger level rating after the Pavlovian conditioning and before transfer test to observed changing in hunger during the task.

A final potential limitation of our study is related to the concept of sensory-specific satiety. The term has been developed by Rolls & Rolls (1997) as a decline in pleasantness of a food during its consumption. In our study, we wanted to manipulate the general physiological state of individuals to investigate the influence of the latter on learning processes and on implicit motivation to obtain a food or cosmetic reward in PIT test. We controlled only satiety level of participants, in other words the suppression of their appetite after ingestion (Tepper & Yeomans, 2017). We did not want to induce a sensory-specific satiety for a type of odour. A potential way to improve our knowledge on the dissociation between food liking and food “wanting” would be to replicate our experiment by giving a meal including sweet foods such strawberry, malt chocolate or butter popcorn.

Finally, concerning our second objective, we did not find a statistically significant correlation between individual trait in anticipatory experience of pleasure and two indicators of “wanting” response in PIT test. Our results suggested that individual trait to anticipate how pleasant or unpleasant something is going to be in the future (expected pleasantness) was independent from “wanting” response in a PIT paradigm.
Conclusion

This experiment showed that overall, participants pressed more for CSs associated to olfactory rewards compared to baseline (no reward associated). However, we could not highlight any effect of individual hunger state, because the experimental manipulation did not provoke a stronger salience for CS_{food} compared to CS_{cosmetic}. Concerning the interaction between expected pleasantness and “wanting” measures, our findings did not reveal a correlation, suggesting that the two concepts were independent.
4. GENERAL DISCUSSION AND CONCLUSIONS
4.1 Summary and integration of the empirical and theoretical parts

This thesis is born from practical questions arising from fragrance and flavour industrial field and consumer insight departments: Is the most pleasant product, the one that consumers really want and buy? Is it possible to measure independently the liking level from the motivation to obtain a specific fragrance? Finally, is it possible to have a more sensitive measure to differentiate fragrance products having similar rewarding proprieties compared to classical hedonic scale?

The objective of our thesis was to answer to practical questions by testing the sensitivity of a promising procedure to measure the difference in motivation to obtain two olfactory stimuli independently from their liking level.

In the theoretical part, we presented a framework to study liking and motivation (the Incentive Salience Theory-IST), the debate in literature to study these psychological concepts in human and the procedure helping to experimentally dissociate liking from implicit motivation to obtain a reward. Particularly, IST posits that pursuit of a positive outcome (reward) depends on three distinct components: motivation to obtain it (wanting), pleasure felt during the consumption of it (liking), and automatic associations and/or cognitive representations of the reward (learning). Animal studies have allowed measuring independently these components. Recently, based on animal methodology, a multitude of methods have been developed to measure the components of reward system on human. However, investigation of these components in human is more complex, mainly because more facets of the same components exist in human and because human are able to fake a lot of behaviours. Two main challenges exist in the concrete measure of liking and wanting in human: 1) the development of methods allowing to study the psychological components of the reward process in the correct unfolding cycle, and 2) the development of methods allowing to operationalize correctly the definition of different forms of liking and wanting; especially of “liking” and “wanting” definitions shared by non-human animals.

A promising method to measure “wanting” is the Pavlovian to Instrumental Transfer (PIT) test. In this thesis, we developed several designs to measure the sensitivity of PIT test in different contexts, in presence of two rewarding outcomes and by using a hand grip to measure the effort mobilized on a voluntary basis according to participant’s motivation.

In the empirical part of this thesis, we provided evidence that PIT paradigm differentiated the “wanting” to obtain a pleasant olfactory stimulus compared to a second pleasant olfactory stimulus when they highly differ in rewarding proprieties. As predicted, the most liked stimulus was also the
most wanted, showing that PIT paradigm allowed to measure difference in “wanting” when two highly olfactory rewards were presented. However, when the difference in liking were very subtle, PIT procedure did not allow to highlight a difference in “wanting” between the two pleasant outcomes even if one outcome was momentary more relevant for individual state. Finally, in this thesis, we wanted to experimentally explore potential linked between expected pleasantness and “wanting” concepts. Since, we did not find any relation between those two concepts, we suggested that individual trait to anticipate how pleasant or unpleasant something is going to be in the future (expected pleasantness) was independent from “wanting” response in our PIT studies.

4.2 Theoretical and practical implications

Challenges in the wanting and liking measurements

Over the past 30 years, the definitions of the reward’s components have been refined based on empirical evidences. The occasional inconsistencies within the different definitions have sometimes provoked issues in the correct operationalization of reward's components. In the theoretical part of this thesis, we presented the two biggest challenges in the concrete measure of liking and wanting in human: 1) the development of methods allowing to study the psychological components of the reward process in the correct unfolding cycle, and 2) the development of methods allowing to operationalize correctly the definition of different forms of liking and wanting; especially of the “liking” and “wanting” definitions shared by non-human animals. Concerning the first challenge, measurements of wanting, liking and learning should follow the correct unfolding of the reward cycle. In each phase of the reward cycle, one specific process is dominant (Kringelbach et al., 2012) and measurements of the psychological components should be done at the right moment to avoid measuring other mental process. Accordingly, in this thesis, we performed the measure of liking immediately after reward consumption and the measure of “wanting” after instrumental action (that was done after reward-cue presentation). Each measure was done independently from the other.

Concerning the second challenge, several methods have been developed to study the different subcomponents of the reward process. In the theoretical part, current methods developed to study the four facets of wanting and liking were presented. In an attempt to find new methods, often scientists incorrectly interpret these concepts. According to the meta-analysis of Pool and colleagues (2016), multiple studies operationalized wanting in similar ways to those that operationalized liking by asking participants to report their expectancies of pleasure for a stimulus. However, what scientists measured is not wanting or liking but the concept of expected pleasantness. The authors suggested that this concept does not correspond to any of the four facets of liking or of wanting but it is an additional
concept underlying cognitive desires referring to the expectations of how pleasant or unpleasant something is going to be in the future.

Methods allowing to measure the explicit facets of liking and wanting has been easier to elaborate compared to the development of methods used to measure the concepts of “liking” and “wanting”. The key reason is that these two components are not directly subjectively experienced and consequently they cannot be measured by direct procedures. The operationalization of the “liking” and “wanting” concepts has been done by means of several procedures. Some of the methods used to measure “liking” and “wanting” are already apply to industrial settings even if methodological limitations exist (Cardello & Jaeger, 2016). For instance, computerized facial and vocal expression methods are high demanding in glossary conceptualization, training, coding; but also implicit techniques such as IAT have label issues with the consequence that often what it is tested is a mix between “liking” and “wanting” instead of a pure measure of each concept (Tibboel et al., 2011).

In order to overcome the difficulties in “wanting” assessment in industry, in the theoretical part of this thesis, we proposed the Pavlovian to Instrumental Transfer (PIT) test. This method is currently used to measure empirically the “wanting” of reward system without asking directly the individual’s cognitive desires. To avoid any potential confound with the concept of expected pleasantness, we decided to use stimuli that could be consumed during the experiment. We performed liking measurement immediately at the end of the task and the odours were consumed instantaneously when perceived (after the extinction phase where we measured the “wanting” component) independently from the “wanting” phase measurement.

The paradigm has not been applied largely to fragrance and flavour field to compared two products having similar liking level. Indeed, a single study showed that PIT procedure could be efficient to measure differences in “wanting” under stress compared to free stress condition and for chocolate odour (Pool et al., 2014). It was a study where an olfactory stimulus was use as primary reward that particularly prone to trigger reward process.

*Originality of the present thesis*

In the empirical part of this thesis, we aimed to investigate the sensitivity of PIT paradigm to measure “wanting” in multiple settings and in presence of two outcomes having similar rewarding proprieties. The final objective was to bring evidence for a potential application of PIT in industrial settings to differentiate two fragrances with similar liking level. In fact, the current challenge in consumer research is to differentiate products that may be often similar in liking. Thus, the classical PIT with one CS+ and one CS- seems not optimized to demonstrate differences in effort mobilized to obtain several putatively different rewarding products. Accordingly, we decided to investigate the sensitivity of the PIT paradigm to differentiate effort mobilized when two odours having similar rewarding
proprieties were used. The originality of the present work was to measure the effort mobilized by means of the same instrumental tool: a hand grip allowing us to measure mobilized effort through the measurements of number of peak and the strain. In fact, we wanted to investigate the difference in the amount of effort mobilized to obtain one odour compared to a second odour instead of differentiating the motivation for two rewards only based on the type of button pressed on a keyboard.

With our experiments, we wanted to investigate the limits of our tool and procedure in the investigation of the effort’s difference between two olfactory rewards. We expected to find a sensitivity of the PIT paradigm to show a transfer effect for the mostly pleasant stimuli compared to mildly pleasant one and an amplified transfer effect for relevant olfactory rewards according to the modified physiological state and personal need.

In the four experiments presented in this thesis, participants were free to respond or not respond on a voluntary basis according to their motivation as often and as quickly as they liked.

**Implications of the four experiments**

In typical individuals not having psychopathology disorders or olfactory troubles, results of experiment 1, showed that the most pleasant olfactory rewards were also the most wanted when two pleasant outcomes highly differ in rewarding proprieties were presented.

In experiment 2, further investigation of this first result was performed by using two stimuli having very subtle difference in rewarding proprieties. Again, individuals mobilized effort for two outcomes previously rated as pleasant, showing that what is liked is also wanted. However, despite a subtle liking difference between the two rewards was observed through hedonic scale, no subtle “wanting” difference was observed by means of PIT measure. This second result had more practical implications than theoretical because, as said previously, the positive correlation was demonstrated. Aware of the practical implications of these results, we simulated internally (at Firmenich, S.A.), these two experiments by testing real fragrances products. We compared two perfumes highly different in rewarding proprieties ($N = 55$) and two perfumes slightly different in rewarding proprieties ($N = 35$). Samples included participants with different olfactory expertise degrees (panellists and students).

The main objectives of these tests were first to investigate whether our results were replicated by using secondary rewards as perfumes and not primary rewards; and second to develop a PIT procedure that gave the opportunity to measure “wanting” for olfactory rewards in a very short time (around 15 minutes) useful in industrial field. Consequently, very drastic changes compared to the more classical PIT procedure were implemented such as for instance reduction of the critical testing phase to one trial compared to 18 presented in this thesis. The results found in the first and second studies of this thesis were replicated internally with real products and brought power to our findings: when perfumes having highly rewarding characteristics were simultaneously used, participants
mobilized more effort to obtain the mostly pleasant rewards compared to the mildly pleasant one.

However, when the reward value was similar for two products, no difference in “wanting” measure was highlighted through the PIT paradigm.

The explication behind these results can be twofold. On the one hand, we assumed that PIT test was not enough sensitive to differentiate “wanting” for stimuli with subtle difference in rewarding proprieties. In this case, PIT paradigm could not be considered a sensitive method. On the other, we assumed no true difference in the amount of effort mobilized to obtain one reward compared to the second. Consequently, PIT measure did not detect it. This hypothesis was supported by the literature. Indeed, from a theoretical point of view, effort mobilized during an action should be adapted to the environment (Frijda, 1987; Sander et al., 2005). If in the environment, two stimuli have similar rewarding proprieties, an organism will invest the same amount of effort to obtain one or the other. In this perspective, the effort mobilized for two similar olfactory stimuli is different only if the two olfactory stimuli induce different behavioural adaptations to changes in the environment. If the stimuli do not cause a different behavioural adaptation, the organism will mobilize the same amount of effort. We assumed that in our second experiment, the rewarding properties of the two stimuli were not so different for the participants and consequently, the effort mobilized by the subjects was the same. The reason behind that can be related to the family of the odours: we used two food odours. This implies that the basic drive behind the choice of one odour or the other, was similar. Before definitively excluding efficiency of PIT paradigm in measuring “wanting” for one reward compared to a second one, we decided to test this second hypothesis and investigate whether changes in physiological states (when two odours from different categories were used) could amplified “wanting” measure for one category compared to another one.

To test this second hypothesis, we performed two additional experiments in which we used olfactory rewards with similar rewarding properties but from two different families (food and cosmetic odours), and in two contexts that increased the pertinence of one category compared to the other. In this case, the effort observed during a PIT test could be different, because the function of the odours diverged and the context imposed required one of those function to be more relevant than the other. One of the main postulate of IST is that “wanting” to obtain an outcome is influenced by the physiological (stress, hunger/satiety, personal needs) and the brain state of the organism. For this reason, in experiment 3, we investigated the sensitivity of the PIT test to measure the personal effort performed to obtain relevant cleansing olfactory stimuli after having induced physical disgust feeling. However, findings showed that even if disgust priming previously occurred, the modified individual’s physiological state did not amplify $C_{cosmetic}$ ability to trigger “wanting” in disgusted participants. We did not provide evidence to the main postulate of the IST (Berridge & Robinson, 1998) arguing that current
physiological state of an individual modulates directly the ability of a Pavlovian conditioned stimulus (CS) to bias attention and trigger “wanting” to obtain the associated reward (UCS). Our result was in contrast with animal (Dickinson & Balleine, 1994; Dickinson & Dawson, 1987; Peciña, Cagniard, Berridge, Aldridge, & Zhuang, 2003; Robinson & Berridge, 2013; Wyvell & Berridge, 2000) and human (Peciña et al., 2006; Pool et al., 2014) studies in which this postulate was validated.

Multiple explanations could be considered. First, we used two stimuli instead of one and this produced a more complex task. Second, the two categories of odours (cosmetic and food) allowed equally to cope with the subjective cleanliness need and thus, individuals pressed equally for the two rewards. Finally, more probable reason was related to the intensity of the disgust feeling induced. Perhaps, subjects were disgusted but not enough to perform an additional effort to obtain cosmetic odours compared to the other category. In fact, a general disgust effect was observed on the trend to perform the task. Probably, at low levels disgust provoked only a general demotivation, an increase in negative and a decrease in positive affect, with the consequence that disgusted individuals decreased more rapidly the effort to perform the task compared to controls. However, the intensity of disgust did not reach a level higher enough to induce an urge to cover environmental hazard.

In the last experiment, we manipulated the physiological state of hunger by inducing a satiation state and measured difference in “wanting” responses for CSs previously associated with food and cosmetic olfactory cues. A different approach was applied compared to experiment 3 and manipulation of physiological state was performed before Pavlovian and instrumental phases. Consequently, investigation of satiety manipulation effects was done on the whole PIT paradigm. We assumed that by performing the manipulation before the Pavlovian and the instrumental phases, we could promote a difference in “wanting” for one reward compared to a second according to previously learned experiences. Particularly, we tested the influence of subjective satiety and subjective hunger levels on learning phases and on instrumental to transfer effect. In this last experiment, we did not find difference in Pavlovian conditioning for the hunger and satiety group for $CS_{food}$ and $CS_{cosmetic}$. Consequently, the basic of the experiment was not filled in and we decided to analysis transfer test data by merging the participants in the two groups and without considering their physiological state. Findings showed that participants performed more squeezes (first “wanting” indicator) and mobilized more force (second “wanting” indicator) for CSs (olfactory pleasant rewards associated) compared to baseline (no-reward associated). With this experiment, we supported the finding of our first experiment and bring additional evidences to the sensibility of the PIT paradigm to measure “wanting” not only where single rewards are used compared to no-reward condition (Pool et al., 2014; Colagiuri et al., 2015; Watson et al., 2014), but in presence of two pleasant rewards.
In addition, concerning liking measure, satiety condition decreased the liking level of the food outcome to the same level as the liking level of the cosmetic outcome. For the physiological state of hunger, we did not find any difference in the learning phases except a higher motivation to perform the instrumental training phase compared to the satiety state.

In the last two experiments of this thesis, we wanted to empirically test the IST postulate that the physiological state or personal need of an individual amplified the “wanting” component. This IST hypothesis is in accordance with the emotional appraisal theories too (Brosch, Sander, Pourtois, & Scherer, 2008; Brosch, Sander, & Scherer, 2007) arguing that the relevance of a reward or a reward-associated cue depends on the interaction between the motivational state of an individual and the reward itself. Multiple research in animal and human had demonstrated this relationship. In our experiments, however, PIT measure was not sensitive enough to highlight the difference between conditions (disgust vs. no-disgust, hunger vs. satiety). Absence of specific transfer effects in experiment 3 could be due to methodological reasons. First, in our experiment, we operationalised “wanting” as the number of peak rather than response choice. Perhaps, the effect was subtler then what we expected and the use of a hand grip to indicate the willingness to obtain one odour compared to a second one gave not the opportunity to highlight subtle differences in “wanting”. Similar issue was highlighted by Lovibond et al. (2015) that used absolute response rate. They assumed that when a small amount of remaining associative strength for the Pavlovian stimulus is present, the choice response format could potentially highlight a difference in “wanting” during the transfer test. However, further research should be done to directly compare the two formats of response.

Second, we used real olfactory stimuli instead of symbolic rewards. This second explication could potentially explain also the absence of difference in Pavlovian conditioning between hunger and satiety group in the experiment 4. Participants concretely consumed the rewards by smelling them during the Pavlovian conditioning phase, the instrumental training and the entire initial part of the transfer test. This consumption could potentially decreased participant’s willingness to obtain olfactory rewards, because their personal (disgust) and physiological (hunger) needs were already filled. Further research should compare differences in effort mobilized by, on one side, replicating the same design but using winning’s points or symbolic images of olfactory rewards during the Pavlovian, instrumental and initial transfer phase; and on the other, by giving the opportunity to consume olfactory rewards only at the end of the task.

Finally, in the theoretical part of this thesis, we presented the concept of expected pleasantness that in some research was interpreted as liking and in other as wanting. Pool et colleagues (2016) suggested that expected pleasantness was a major conceptual confound underlying the challenge in operationalization of reward components in humans. In their meta-analysis, the authors reported that in 84 studies examined, 25% of them measured expected pleasantness to reflect liking and 13% to
reflect wanting. However, expected pleasantness could be defined as expectancies of how pleasurable something is going to be and does not correspond conceptually to either liking or wanting components. It determines cognitive desires which relies on a motivational system (the goal-directed system) that it is different from the one of “wanting” (the Pavlovian system) (Berridge & Aldridge, 2008). In this thesis, we wanted to exploratory tested whether the concept of expected pleasantness could empirically correlate to the concept of “wanting”. We measured the capacity of individuals to image a potential reward before the beginning of the PIT test and we correlated this score with the “wanting” score in the critical phase of the PIT test. Correlation between those concepts would contradict Pool and colleagues’ suggestion and absence of correlation potentially corroborate their assumption. Our exploratory investigation, showed that these two psychological components did not correlated in any of our experiments, revealing that “wanting” component was independent from the expectations about pleasure. Our findings sustained Pool and colleagues’ proposition that expected pleasantness is different from “wanting”. Further research should be done to bring more evidences to this exploratory result.

4.3 Limitations and perspectives

4.3.1 Limitations

Several limitations may explain our results. Some of them were listed below.

Integral of total force indicator

A potential limitation of the presented thesis might be the use of exerted force as an indicator of energy investment.

First, we explicitly showed to participants to correctly use the handgrip in order to receive olfactory rewards. They had to press the hand grip and move the mercury, of the computerized thermometer, up to the top of it and down again to zero. The participants were then free to press as often as quickly they wanted according to their motivation. This was an explicitly claim permitting us to count the number of squeezes reaching at least 50% or 70% (criterion varied every 1s) of the participants’ maximal force.

With this type of instruction, we could potentially have contradictory results between the first and second indicators in the extinction phase of the transfer test. In fact, it could be the case that after some trials where a person did not receive anymore the olfactory rewards, the individual changed the strategy to press to improve his/her chances to obtain something. For instance, a person could decide to maintain pressed the hand grip in order to maintain the mercury to the top of the thermometer. In this case, the participant performed only one squeeze and the first indicator (number of squeezes)
showed that the participant was little motivated to obtain the reward compared to the second indicator (total force) that indicated a very high individual motivation for the said reward. We were aware of the potential issue and we analysed the data at individual level for the extinction phase of the test. Surprisingly, this scenario never happened. In further research, a free response format would be more appropriate to measure the total force.

Second, the exerted force of a participant is not related only to his motivation but it is depended from physiological and anatomical elements independent from his motivation. However, by using within-subject designs, we could assume that these potential factors are randomly distributed.

In academic research exists alternative methods to assess energy investment such as the oxygen consumption measure (Sherwood et al, 1986). However, for industrial settings this measure is less comfortable and more expensive to implement and it give only a general idea of the whole-body energy metabolism (not only the energy used specifically during the instrumental action).

**Online oral instruction**

We gave oral standardized instructions during each phase of the PIT test. However, sometimes participants did not understand and asked additional questions to be sure of performing correctly the multiple phases of the paradigm. The investigator trained herself to know the exact words to say to help participants without giving to much detail and by being extremely cautioning not reveal the goal of each phase. However, if multiple investigators run the study oral instructions gave by person for conditioning phases could increase the risk of making errors. A potential solution would be to give recorded oral instructions as presented in Colagiuri & Lovibond (2015).

**Relationship between olfactory stimuli and coloured visual stimuli**

Literature showed that odour intensity perceived can be increase by the colour of an image presented simultaneously with the odour (i.e odour of strawberry presented with the image of a red strawberry) (Zellner et al., 1990). One could argue that the coloured visual images used during the Pavlovian phase and transfer test had influenced the associations with the olfactory stimuli. In our experiments this bias was excluded, because the images and the odour were randomized.

**The duration of the conditioning trainings phase**

In our experiment 1, the first phase of training (instrumental) englobed 24 trials and the second phase of training (Pavlovian) englobed 36 trials. In the other experiments (2, 3 and 4), the duration of the first phase was reduced because participants could learn correctly to use the handgrip after 4 trials. With this methodological adaptation, the advantage was to reduce the duration of the whole PIT. However, this methodological change could negatively influence the transfer effect during the critical
phase of the PIT test (Holmes et al., 2010) and potentially explain why no effect were observed during the experiment 2, experiment 3. However, the observation of a difference in transfer in experiment 4 between hunger and satiety groups could potentially assume that in our design the reduction of the phase 1 did not impact the transfer effect. In addition, we performed internally (Firmenich, S.A.), the experiment 1 and 2 by changing the order of the Pavlovian and instrumental phase. Findings showed No statistical significant difference in the transfer effect compared to the two experiments presented in this thesis. Considering these points, it seems improbable to us that our results can be accounted for by a bias in the length of the first phase of the conditionings.

Instrumental extinction vs. Instrumental renforcement
Lovibond et al. (2015) found that extinction produced a significant reduction in the magnitude of the PIT effect. However, this finding is not in line with other human PIT that tested the effect of Pavlovian extinction in human (Hogarth et al., 2014; Rosas, Paredes-Olay, García-Gutiérrez, Espinosa & Abad, 2010) and in animal (Delamater, 1996; Holmes et al., 2010). To avoid this potential effect of extinction, we reproduced internally (Firmenich, S.A.), the experiment 1 and 2 by using real fragrance product and by adding some methodological change to our PIT test. The most relevant consisted to add to the critical part of the PIT test, an instrumental reinforcement phase after some trails performed under instrumental extinction. No positive effects of instrumental reinforcement were observed on transfer effect. Similar findings were observed compared to the results found in experiment 1 and 2 presented in this thesis.

Difference in effort mobilized by means of a dynamometer
In this thesis, we wanted to measure difference in effort mobilized for two pleasant stimuli. The paradigm is enough sensitive to be use with two olfactory stimuli highly different in rewarding proprieties. However, when the reinforcing difference between two rewards are too subtle, the effort mobilized format does not highlight a difference in “wanting”. In experiment 3 and 4, we can assume that the effect was subtler then what we expected. Moreover, the use of a hand grip to indicate the willingness to obtain one odour compared to a second one, gave probably not the opportunity to highlight subtle differences in “wanting”. Same conclusion has been highlighted by Lovibond et al. (2015) that used a rate measure instead of the choice of a key for each reward. Authors did not find any difference in “wanting” for the two rewards.

Awareness and unawareness of the Pavlovian contingency and the transfer effect
Multiple research showed that the contingency awareness plays a critical role in human associative learning (e.g., Mitchell, De Houwer, & Lovibond, 2009) and in reward-based behaviour specifically
(e.g., Hogarth, Dickinson, Wright, Kouvaraki, & Duka, 2007; Hogarth & Duka, 2006). Some authors have investigated with post-experimental questions the contingency awareness of the different phases of the PIT paradigm (Talmi et al., 2008; Lovibond & Colagiuri, 2013; Lovibond et al., 2015b). Talmi and co-workers (2008), asked the participants at the end of the task to answer to the following question: “sometimes there were sounds playing with the grip task and images of different colours presented in the background. How did that affect you, if at all?” Analysis revealed that the PIT effect was present in “aware” participants but not in “unaware” participants.

In Lovibond & Colagiuri (2013), participants rated how often each of the two coloured lights was followed immediately by chocolate during the middle part of the experiment, using 100-mm visual analogue scales from 0% (never) to 100% (always).

Lovibond et al. (2015) used a forced choice questions about the non-extinguished stimuli: “Which of the three lights was most/least often followed by chocolate?”

In all experiments, the authors found that aware participants mobilized a higher effort in the transfer test, suggesting that the PIT procedure in humans could measure explicit wanting rather than a pure measure of “wanting”. Further research should be done to investigate the influence of implicit and explicit facets of wanting in PIT test.
4.3.2 Future Perspectives

The experiments proposed in this thesis allowed to test and to define the limitations of the PIT paradigm in highlighting the implicit motivation to obtain pleasant olfactory stimuli by means of an effort task.

Recently, the effectiveness in using tasks in which the measure of implicit motivation is assessed by effort mobilized by arms has been challenged (Rougier, in press.). Some authors suggest the utility in using paradigms where motivational assessment is done by measuring the approach/avoidance behaviours performed by the whole-body. In Rougier et al., authors propose the Visual Approach/Avoidance by the Self Task (VAAST) as a potential procedure to measure the motivation to obtain a specific stimulus through visual observation of the whole-self moving toward or away from that stimuli. With this paradigm, the focus is on visual information associated with whole-body movements instead of motor aspects associated with arm movements. In this task, whole visual environment (i.e., the background image and the target word) is zoomed in or our according to the subjects’ approach/avoidance action. When the participant wants to approach something, the whole visual environment is zoomed in. When the participant wants to avoid something, the whole visual environment is zoomed out. This procedure gives to the participant, a visual impression of walking forward or backward in the video game’s environment.

The main advantage of this task compared to a manikin or a joystick task, is the avoidance of ambiguity in the interpretation of arm movements. Arm flexions or extension can both represent approach behaviour to obtain something as well as an avoidance behaviour to withdraw arm from something. This level of ambiguity is very low for movement of the whole body, because forward and backward movements of the whole body refer mostly to approach and avoidance behaviours.

A potential perspective would then to adapt a whole-body movement task such as the VAAST to industrial setting and testing the sensitivity to measure approach/avoidance motivation to obtain one pleasant olfactory stimulus compared to a second one.
4.4 Conclusion

The research of new methods allowing to differentiate products that did not differ in liking seems to be difficult. A growing number of studies report the usefulness of measuring other indicators to differentiate two products when liking measurement for these stimuli do not show any difference (King & Meiselman, 2010; King et al., 2013; Laros & Steenkamp, 2005; Ng et al., 2013a; Porcherot et al., 2010; Warrenburg, 2005).

The findings of our thesis showed the limits of an additional paradigm when liking measurement show subtle difference between two olfactory rewards. The PIT procedure highlighted the “wanting” for single rewards or fragrances products compared to airless (Pool et al., 2014; Cereghetti et al., in prep.) or for olfactory stimuli having high differences in rewarding proprieties. However, we concluded that PIT test is not more sensitive and do not bring additional information compared to a classical hedonic method used regularly in industry.
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6. RÉSUMÉ EN FRANÇAIS
Introduction

Pendant longtemps, pour les analyses sensorielles et les études consommateurs, la mesure du plaisir était définie comme la meilleure approche pour comprendre les préférences et le comportement du choix alimentaire (De Graaf et al., 2005; Kamen, 1962; Peryam & Pilgrim, 1957; Pilgrim, 1961; Pilgrim & Kramen, 1963; Schutz, 1957). En effet, les expériences en laboratoire montraient que les produits les plus appréciés étaient aussi les produits les plus choisi par les consommateurs (De Graaf et al., 2005). Or, les nouveaux produits lancés sur le marché ne sont pas toujours les plus achetés et n’ont donc pas le succès escompté par les vendeurs. Il est donc nécessaire de comprendre les motivations incitants le choix d’un produit, qui ne peuvent pas être réduites à la simple évaluation du plaisir issu par l’obtention du produit souhaité.

Les méthodes utilisées dans l’industrie découlent de la recherche appliquée et de la recherche fondamentale. En psychologie et en neurosciences, la théorie dénommée « Incentive Salience » (IST) est utilisée pour expliquer comment nos actions quotidiennes sont influencées à la fois par des stimulations plaisantes et déplaisantes. La théorie postule que la quête d’une récompense n’est pas directement proportionnelle au plaisir provoqué par l’obtention du produit, mais qu’elle est influencée par la motivation qu’un individu est prêt à investir pour obtenir cette récompense. Selon les pionniers de cette théorie, la recherche d’une récompense est influencée par la motivation à obtenir cette récompense (wanting/incentive salience), le plaisir (liking) par la consommation de la récompense et par les associations et représentations cognitives de la récompense (learning) (Robinson & Berridge, 1993, 2003; Berridge & Kringelbach, 2008). Sur la base des études animales, les auteurs montrent que le plaisir peut être mesuré indépendamment de la motivation. La composante hédonique est mesurée à travers l’analyse des expressions faciales et la composante motivationnelle à travers la mesure de l’effort mobilisé pour obtenir une récompense. Normalement, les trois composantes corrèlent positivement (on « veut » ce qu’on « aime » et ce qu’on a « appris » à aimer à partir des expériences passées). Cependant dans des cas spécifiques (comme dans les addictions), ces composantes peuvent être dissociées, pouvant ainsi donner lieu à des comportements apparemment irrationnels où l’individu investit beaucoup d’effort afin d’obtenir une récompense qui ne sera cependant pas appréciée une fois obtenue (e.g., Wyvell & Berridge, 2000). La mesure de ces composantes chez l’Homme est plus récente et complexe par rapport à celle des animaux. En plus, il n’est pas possible d’appliquer directement les méthodes animales à l’homme. En effet, les humains sont capables de simuler les expressions faciales et inhiber les pulsions de consommation (Tibboel et al., 2011).

Récemment, une multitude des méthodes a été créé pour étudier ces composantes chez l’humain. Cependant, plusieurs difficultés sont apparues dans les études conduites chez l’Homme pour...
opérationnaliser de manière cohérente les construits de motivation à obtenir une récompense et de plaisir formulés sur la base de la recherche chez l’animal (Pool et al., 2016). Deux défis principaux existent dans la mesure concrète de la composante motivationnelle et hédonique chez l’Homme : 1) le développement de méthodes permettant d’étudier les composantes psychologiques de la récompense respectant le cycle correct du système de récompense 2) le développement de méthodes permettant d’opérationnaliser correctement les définitions de la composante motivationnelle et hédonique.

Un paradigme prometteur pour étudier la composante motivationnelle chez l’humain est le Pavlovian to Instrumental Transfer (PIT). Le modèle permet de mesurer la composante motivationnelle (l’effort qu’on organisme est prêt à investir) en absence de la composante hédonique (le plaisir pendant l’obtention d’une récompense) et il peut, donc, être potentiellement appliqué à l’industrie pour mesurer la motivation du consommateur à vouloir un produit en présence d’un autre. Cependant, le PIT n’a jamais été testé en présence des deux stimuli olfactifs. Le but de cette thèse consiste (i) à tester la procédure en présence de deux stimulations olfactives (ii) à tester la procédure en fonction des changements de l’état physiologique (iii) à dissocier expérimentalement la composante motivationnelle de la composante hédonique en fonction des besoins induits chez les participants. D’un point de vue pratique, l’objectif de cette thèse consiste à prouver que le paradigme PIT peut être une méthode plus efficace par rapport à l’échelle hédonique utilisée couramment en entreprise.

Dans la partie théorique (chapitre 2) de cette thèse, nous avons défini le concept de récompense et de motivation dans l’optique de la théorie « Incentive Salience ». Nous avons, ensuite, effectué une revue de la littérature existante chez l’Homme concernant les méthodes développées pour mesurer la composante motivationnelle. Ensuite, nous avons présenté les différentes études dans lesquelles le paradigme PIT a été utilisé chez l’Homme.

Dans la partie empirique de cette thèse (chapitre 3), nous avons présenté les quatre expériences qui nous ont permis de tester nos hypothèses. Nous avons décidé de démarrer notre investigation en développant un paradigme PIT qui mesurerait la motivation à obtenir des stimulations olfactives. En effet, les odeurs sont des stimuli idéaux pour influencer la composante motivationnelle du système de récompense, vu qu’il s’agit de récompenses primaires ayant une valeur innée et une importance biologique (Gottfried, 2011), tout en étant facilement manipulables.

Dans la première étude, nous nous sommes questionnés sur la sensibilité du paradigme PIT à mesurer la composante motivationnelle d’une stimulation olfactive par rapport à une deuxième ayant des propriétés « récompensâtes » différentes (section 3.3). Dans la deuxième étude, nous avons reproduit la même procédure mais nous avons mesurer la composante motivationnelle d’une stimulation
olfactive par rapport à une deuxième ayant des propriétés « récompensées » très semblable (section 3.3). Sur la base des résultats de ces deux expériences, nous avons investigué les facteurs influençant la composante motivationnelle. En effet, Berridge et Robinson (1998) proposent que la motivation à obtenir une récompense soit directement modulée par l’état physiologique actuel de l’individu ou par ses besoins momentanés. Dans la troisième étude, nous avons donc testé cette hypothèse en induisant un état de dégoût chez des individus sains et testé leur réponse motivationnelle à obtenir des stimulations olfactives cosmétiques et alimentaires (non-cosmétiques) ayant le même niveau de plaisir (section 3.4). Dans la quatrième étude, nous avons testé les effets de satiété sur les phases d’apprentissage du PIT et sur la composante motivationnelle (section 3.5). Enfin dans le chapitre 4, nous avons combiné nos résultats avec le cadre théorique et discuté les implications théoriques et pratiques de nos résultats.

Dans les prochains chapitres, nous allons présenter en détails la partie théorique, empirique, la discussion et la conclusion découlant de cette thèse.

**Partie Théorique**

La recherche du plaisir est essentielle dans notre quotidien : chaque organisme recherche principalement à vivre des situations positives et d’éviter les situations négatives. Au quotidien, les actions sont souvent influencées par des éléments de l’environnement qui peuvent nous inciter vers ou nous arrêter d’amorcer une action spécifique. Par exemple, percevoir l’odeur de notre repas préféré dans la rue, peut nous pousser à chercher celui-là dans les restaurants aux alentours. Une récompense peut être définie comme « un stimulus, un objet, un événement ou une situation qui potentiellement nous incite à s’approcher et à le consumer » (Schultz, 2015, p. 5). Les propriétés motivationnelles et attrayantes d’un stimulus ne sont pas entièrement définies par ses propriétés physiques mais aussi par les réactions comportementales qu’elles suscitent chez une personne (Schultz, 2015).

D’un point de vue évolutif, la récompense a la fonction de nous pousser à manger, à boire et à nous reproduire pour la survie de l’espèce et de nous-même. Une récompense est telle si elle provoque du plaisir ou permet d’inhiber la douleur et rétablir un état physiologique d’équilibre.

Un cadre bien établi du processus de récompense est proposé par la théorie de l’*incentive salience (IST)* qui soutient que la poursuite d’une récompense est influencée par le plaisir (composante hédonique) éprouvé pendant la consommation de la récompense, la motivation (la composante motivationnelle) à obtenir la récompense et aussi par l’apprentissage des associations instrumentales, pavlovienne et des représentations cognitives de la récompense (la composante d’apprentissage) (Robinson & Berridge, 1998, 2003; Berridge & Kringelbach, 2008). La théorie de l’*incentive salience*
propose quatre définitions des composantes du système de récompense : la définition mentale, la définition neurologique, la définition de l’effet et la définition de l’utilité. À travers une définition mentale, les composantes sont définies en tant que processus psychologiques. Chaque composante a été définie en fonction de la présence ou l’absence de guillemets. Les composantes « motivationnelle », « hédonique » et « d’apprentissage » avec les guillemets font référence à la définition donnée par la théorie de l’incentive salience. La composante motivationnelle était définie en tant que sentiment d’envie irrésistible, la composante hédonique en tant que réaction hédonique et la composante d’apprentissage en tant qu’associations mentales apprises par conditionnement. La composante motivationnelle sans les guillemets correspond au désir subjectif conscient relié aux expériences plaisantes du passé. La composante hédonique sans les guillemets réfère au concept de plaisir tout court (Robinson & Berridge, 1993). La composante d’apprentissage sans les guillemets correspond aux représentations et prédictions cognitives sur des récompenses futures. En 2010, les trois composantes ont été définies aussi en tant que processus psychologiques explicites et implicites qui se différencient en fonction de l’accès à la conscience. Les processus explicites sont consciemment éprouvés et incluent les concepts psychologiques de plaisir explicite, de bonheur, de désir et d’espérance. Les processus implicites sont potentiellement inconscients : Ils peuvent opérer à un niveau qui n’est pas toujours directement accessible à la conscience et correspondent aux concepts d’incentive salience (« wanting ») et de réaction hédonique. La différenciation entre le processus implicite et les processus explicites est beaucoup plus pertinente pour la composante motivationnelle par rapport à la composante hédonique. En effet, les processus explicites et implicites de la composante hédonique renvoient à l’impact hédonique de la consommation d’une récompense. Cependant, la définition explicite de la composante motivationnelle se réfère à un processus différent par rapport au processus à la base de la définition implicite. Elle fait référence au sentiment subjectif d’attraction vers un objet désiré et dépend des expériences hédoniques passées. De l’autre côté, la définition implicite de la composante motivationnelle se réfère à la définition d’incentive salience et du sentiment d’envie irrésistible.

Ces composantes psychologiques correspondent à des activations cérébrales spécifiques. La composante hédonique est le résultat de l’activation synchronisée des régions limitées à l’intérieur des nucleus accumbens (NAcc), et du ventral pallidum. La composante motivationnelle est déclenchée par l’activation d’une région spécifique à l’intérieur du système dopaminergique mesolimbique (Berridge and Robinson, 2003; Dickinson and Balleine, 2002; Everitt and Robbins, 2005; Kelley et al., 2005; Kringelbach, 2005; Kringelbach and Berridge, 2008; Leknes and Tracey, 2008; Schultz, 2006).

Pour ce qui concerne la définition de l’effet, seulement la composante motivationnelle a été définie. Selon cette définition une récompense et les éléments associés à cette récompense (stimuli
conditionné-SC), peuvent agir en tant qu‘aimant motivationnel et attirer l’attention. Par conséquence, les différents éléments et la récompense deviennent de renforçateurs de la récompense et provoques une augmentation de l’effort pour les obtenir.

Finalement, à travers la définition de l’utilité, les auteurs présentent les buts spécifiques de chaque composante.

Ces quatre définitions permettent de mieux comprendre les composantes du système de récompense. Cependant, les inconsistances occasionnelles parmi les différentes définitions engendrent des soucis de compréhension et une correcte opérationnalisation des composantes.

Deux défis principaux existent dans la mesure concrète de la composante motivationnelle et hédonique chez l’homme : 1) le développement de méthodes permettant d’étudier les composantes psychologiques de la récompense respectant le cycle correct du système de récompense 2) le développement de méthodes permettant d’opérationnaliser correctement les définitions de la composante motivationnelle et hédonique; particulièrement des facettes implicites des composantes.

Une méthode prometteuse de mesurer la composante motivationnelle implicite est le Pavlovian to Instrumental Transfer (PIT). Cette méthode a été utilisé par notre laboratoire en présence d’une récompense olfactive plaisante (Pool et al., 2014) qui a montré la sensibilité du paradigme à mesurer l’augmentation de la motivation implicite pour cette odeur dans un état physiologique de stress par rapport à une situation sans stress (Pool et al., 2014). Cependant, il n’a pas encore été testé en présence de deux récompenses olfactives. Dans cette thèse, nous avons développé plusieurs designs pour mesurer la sensibilité du paradigme PIT dans différents contextes, en présence de deux récompenses olfactives et en utilisant un capteur de force pour mesurer l’effort mobilisé du participant.

Ce paradigme inclut deux phases de conditionnement séparées (instrumentale et Pavlovienne) suivi par une phase de test dans laquelle nous mesurons les effets des stimuli Pavloviens sur l’action instrumentale (effet PIT). Le concept de PIT se réfère à l’habilité d’un stimulus Pavlovien (qui prédit une récompense) de provoquer une action instrumentale pour obtenir cette récompense (Estes, 1943, 1948; Kruse et al., 1983; Rescorla and Solomon, 1967). Le paradigme PIT est souvent utilisé pour investiguer l’effet de certains éléments externes sur le comportement d’un organisme dans des activités comme boire, manger ou chercher de la drogue (Everitt and Robbins, 2005). Les données sur les effets de transfert découlent principalement de la recherche animale, notamment sur les souris (Crombag et al., 2008 a, b; Johnson et al., 2007; Mead and Stephens, 2003a, b; Sanders et al., 2007), les rats (Balleine, 1994; Colwill and Motzkin, 1994; Corbit and Balleine, 2003; Delamater, 1995, 1996; Delamater and Holland, 2008; Edgar et al., 1981; Estes, 1943, 1948; Holland, 2004; Holland & Gallagher, 2003; Lovibond, 1981; Meltzer and Hamm, 1974a, 1974b, 1978; Meltzer and Brahlek, 1970; Rescorla, 1994 a, b, 1997, 2000), les singes (Henton and Brady, 1970), et les pigeons (Herrnstein and Morse, 1957; Lolordo, 1971; Overmier et al., 1983). Récemment, le paradigme a été
appliqué à la recherche chez l’humain sur des populations saines et pathologiques afin de comprendre les effets du transfert à partir d’une perspective à la fois psychologique et neurologique (Bray et al., 2008; Talmi et al., 2008; Watson et al., 2014; Pool et al., 2015; Huys et al., 2016; Garofalo et al., 2015; Cartoni et al., 2015; Lewis et al., 2013; Nadler et al., 2011; Corbit et al., 2005; Hogarth et al., 2007; Pareded-Olay et al., 2002).

Partie Empirique

Dans la partie empirique, nous avons présenté les quatre expériences développées pour tester la sensibilité du paradigme PIT. A travers nos expériences, nous avons voulu tester les limites du capteur de force et de la procédure expérimentale dans l’investigation des différences d’effort entre deux récompenses olfactives. En effet, notre objectif était de mesurer la différence dans l’effort mobilisé pour obtenir une récompense olfactive par rapport à une deuxième récompense olfactive plutôt que différencier la motivation pour deux récompenses olfactives en se basant seulement sur le type de touche utilisée sur le clavier. C’est pourquoi, nous avons décidé de mesurer l’effort mobilisé à travers la mesure du nombre des piques et de la force totale exercée sur le capteur de force. Le premier indicateur prenait en considération le nombre de pressions exercées sur le capteur de force excédant le 50-70% de la force maximale du participant. Le deuxième indicateur mesurait la force totale exercée (aire sous la courbe du signal du capteur) pendant les 12 seconds d’évaluation.

La première expérience visait à investiguer la sensibilité de l’outil en présence de deux récompenses avec un plaisir « récompensant » qui variait considérablement entre elles. La deuxième expérience visait à tester la sensibilité de l’outil en présence de plusieurs récompenses présentant des plaisirs « récompensants » voisins. Les résultats des deux expériences suggéraient que le PIT était assez sensible pour mesurer l’effort mobilisé par une personne en présence des deux récompenses avec un plaisir « récompensant » qui variait considérablement entre elles ; par contre, le PIT ne semblait pas être une mesure assez sensitive pour mesurer le « wanting » pour des récompenses présentant des plaisirs « récompensants » voisins.

Se basant sur la proposition de la théorie IST qui suggère que l’effort mobilisé par une personne est influencé aussi par son état physiologique (soif, faim, besoin reproductif) et ses besoins personnels, la troisième et la quatrième expérience visaient à investiguer la sensibilité du paradigme PIT à mesurer les changements de la motivation implicite induite par le dégoût et la satiété pour obtenir une récompense olfactive pertinente pour l’état actuel de la personne. En particulier, dans la troisième expérience nous avons manipulé le sentiment de dégoût physique à travers une tâche d’induction dans laquelle des stimuli visuels dégoutants et un stimulus olfactif malodorant étaient utilisés. Le but était d’induire un sentiment de dégoût qui provoquait une augmentation de la motivation implicite à obtenir des stimuli olfactifs cosmétiques (par exemple, odeur de savon) par rapport à des stimuli
olfactifs non-cosmétiques, mais alimentaires (par exemple, odeur de fraise) afin de faire face au sentiment de dégoût physique. Les stimuli olfactifs avaient les mêmes plaisirs « récompensants ». Nous avons supposé un effet général négatif du dégoût sur l’évolution de la motivation implicite par rapport au groupe contrôle qui continuaient à presser constamment le capteur de force. De plus, nous avons présumé un effet spécifique du dégoût (observable à travers le PIT) à vouloir obtenir des stimuli olfactifs cosmétiques (par exemple, odeur de savon) par rapport à des stimuli olfactifs non-cosmétiques (par exemple, odeur de fraise). Les résultats suggéraient un niveau de démotivation générale (induite par le sentiment de dégoût) à faire la tâche d’effort. Cependant, le paradigme PIT n’a pas permis de mettre en évidence un effort majeur pour obtenir des stimuli olfactifs cosmétiques par rapport des stimuli olfactifs alimentaires (non-cosmétiques).

Sur la base de ces résultats, nous avons décidé d’augmenter la probabilité d’obtenir une différence dans la mesure de l’effort physique pour obtenir une récompense olfactive pertinente pour l’état actuel de la personne. Dans l’expérience 4, nous avons testé l’effet de la satiété non seulement sur la phase finale du paradigme PIT mais aussi sur les phases d’apprentissage. Nous avons donc induit un état de satiété et mesuré la sensibilité du paradigme à détecter l’effort physique pour obtenir des récompenses olfactives alimentaires et cosmétiques (no-alimentaires). Nous avons fait l’hypothèse que les personnes dans un état de satiété étaient poussées à faire moins d’effort à obtenir des récompenses olfactives alimentaires par rapport à des personnes dans un état de faim. Les résultats ont montré une absence de différences statistiquement significatives entre le groupe faim et le group satiété dans la phase Pavlovienne de conditionnement. Cela, nous a donc empêché de tester l’effet transfer en fonction du groupe. Nous avons, par conséquence, analysé les données sur l’ensemble des participants sans tenir en considération l’état physiologique des individus. Les résultats ont montré que les participants mobilisés plus d’effort pour obtenir les images associées en précédent avec des récompenses par rapport aux images qui n’ont pas été précédemment associées avec des récompenses. Ces résultats sont en accord avec la première expérience et soutiennent les études où qui montrent que le PIT permet de mettre en évidence une mobilisation majeure de l’effort pour des récompenses par rapport à une Baseline (Pool et al., 2014).

Discussion

Cette thèse est née à partir de questions pratiques résultant du domaine industriel de la création de fragrances et d’arômes : est-ce que le produit le plus agréable, est aussi celui que les consommateurs veulent vraiment ? Est-ce qu’il est possible de mesurer indépendamment le niveau de plaisir du niveau de motivation qui pousse un individu à obtenir une odeur spécifique ? Finalement, est-ce qu’il est possible d’avoir une mesure plus sensitive que l’échelle h édonique classique pour différencier des fragrances et des arômes ayant un plaisir « récompensant » semblable ?
En psychologie et en neuroscience, la théorie nommée « incentive salience theory » permet d’étudier la motivation et le plaisir de façon indépendante. Elle suggère l’existence de trois composantes du système de récompense : la composante hédonique, motivationnelle et d’apprentissage. Cette théorie a été largement utilisée dans l’étude du système de récompense chez les animaux et, plus récemment, a été utilisée aussi chez l’Homme. Cependant, deux défis principaux existent dans la mesure concrète des composantes du système de récompense chez l’homme : 1) le développement de méthodes permettant d’étudier les composants psychologiques de la récompense respectant le cycle correct du système de récompense 2) le développement de méthodes permettant d’opérationnaliser correctement les définitions de la composante motivationnelle et hédonique; particulièrement des deux facettes implicites de chaque composante partagées aussi par les animaux.

En ce qui concerne le premier défi, les mesures de la motivation, du plaisir et de l’apprentissage devraient être exécutées au bon moment du cycle de récompense. Dans chaque phase du cycle de récompense, une composante psychologique est dominante (Kringelbach et al., 2012) et les mesures des composantes psychologiques devraient être faites au bon moment pour éviter de mesurer d’autres processus mentaux. Par conséquent, dans cette thèse, nous avons exécuté la mesure de plaisir immédiatement après la consommation de récompenses et la mesure de la composante implicite de la motivation après l’action instrumentale (qui a été faite après la présentation du stimulus associé avec la récompense). Chaque mesure a été faite indépendamment l’une de l’autre.

En ce qui concerne le deuxième défi, nous avons présenté les méthodes actuelles développées pour étudier les quatre facettes de la composante hédonique et motivationnelle. Dans une tentative de trouver de nouvelles mesures, certains scientifiques interprètent de façon inexacte ces concepts. Des multiples études ont opérationnalisé le construit de motivation et de plaisir de la même façon en demandant aux participants de rapporter leurs attentes de plaisir pour un stimulus. Cependant, ce qui a été mesuré, ce n’était pas la motivation ou le plaisir mais le concept d’agréabilité anticipée (Pool et al., 2016). Ce concept ne correspond à aucune des quatre facettes de construits de motivation ou de plaisir, mais c’est un concept supplémentaire étant à la base de désirs cognitifs se référant aux attentes futures sur le niveau de plaisir ou de déplaisir d’un stimulus.

Afin de surmonter les difficultés dans l’évaluation de la composante motivationnelle implicite en industrie, dans la partie théorique de cette thèse, nous avons proposé une méthode prometteuse appelée Pavlovian to Instrumental Transfer (PIT). Cette méthode permet de mesurer empiriquement la motivation implicite sans demander directement au participant ses désirs cognitifs. Dans cette thèse, nous avons exécuté la mesure de la composante hédonique immédiatement à la fin de la phase d’extinction où nous avons mesuré indépendamment la composante motivationnelle. Cette procédure et l’utilisation des récompenses olfactives réelles, nous ont permis d’éviter de potentielles erreurs et de mesurer erronément le concept d’agréabilité anticipée.
Le paradigme PIT n’a pas été fréquemment utilisé avec des stimuli olfactifs. En particulier, la sensibilité du paradigme PIT n’a jamais été testée en présence de deux récompenses olfactives. L’objectif primaire de cette thèse a été de mesurer la sensibilité du paradigme PIT à mesurer les variations de motivation implicite pour une récompense en présence d’une deuxième et en fonction de l’état physiologique du participant. L’objectif ultime de cette thèse était d’apporter des évidences pour une potentielle application industrielle du PIT test dans la différentiation des fragrances ou d’arômes ayant un niveau de plaisir semblable.

Quatre expériences ont été créés afin de tester l’outil dans lesquelles les sujets étaient libres de répondre ou de ne pas répondre en fonction de leur motivation aussi souvent et aussi rapidement qu’ils le souhaitaient. Chez des individus n’ayant pas des troubles psychopathologiques ou olfactifs, nous avons démontré empiriquement une corrélation positive entre la composante hédonique et la composante motivationnelle. En effet, dans la première expérience, les résultats ont montré qu’en présence de deux stimulations olfactives avec un plaisir « récompensant » très différent, la récompense olfactive la plus agréable était aussi la plus voulue. Dans la deuxième expérience, nous avons poussé l’investigation de ce résultat en utilisant deux stimuli présentant des plaisirs « récompensant » voisins. Nous avons trouvé de nouveau une corrélation positive entre la composante hédonique et la composante motivationnelle, parce que les individus ont mobilisé une quantité d’effort pour deux stimuli olfactifs précédemment évalués comme agréables. Cependant, malgré une subtile différence au niveau du plaisir consommatique, aucune différence de motivation implicite n’a été observée. Ce deuxième résultat avait des implications plutôt pratiques que théorique parce que, comme dit précédemment, la corrélation positive a été démontrée. Conscient des implications pratiques de ces résultats, nous avons testé en interne (Firmenich S.A.), ces deux expériences en testant des parfums réels. Les résultats précédemment présentés, ont été reproduits. L’explication derrière ces résultats peut être double. D’une part, nous avons supposé que le test PIT ne fût pas assez sensible pour différencier la motivation implicite pour des stimuli avec une différence subtile au niveau du plaisir « récompensant ». D’autre part, nous avons présumé une absence de différence au niveau de l’effort mobilisé pour obtenir une récompense comparée à une deuxième. Par conséquent, la mesure PIT n’a pas détecté cette différence motivationnelle.

Afin de tester cette deuxième hypothèse, nous avons exécuté deux expériences supplémentaires dans lesquelles nous avons utilisé des récompenses olfactives avec des propriétés « récompensâtes » semblables, mais provenant de deux familles différentes (des odeurs alimentaires et cosmétiques) et dans deux états physiologiques qui ont augmenté la pertinence d’une catégorie comparée à l’autre. Selon la théorie de l’incentive salience, la composante motivationnelle est influencée par l’état physiologique de l’individu qui peut soudainement modifier la relevance d’une récompense et des éléments associés (stimuli conditionnés-SC) (Zhang, Berridge, Tindell, Smith, & Aldridge, 2009).
En particulier, dans la troisième expérience, nous avons induit du dégoût physique et examiné la sensibilité du test PIT à mesurer l'effort mobilisé afin d'obtenir des stimuli olfactifs cosmétiques par rapport à des stimuli alimentaires (non-cosmétiques). Cependant, même si les sujets ont été dégoûtés, l'induction n'a pas modifié l'état physiologique de manière à amplifier l'habilité du stimulus conditionné (SC) à provoquer une motivation implicite majeure. Par conséquent, nous n'avons pas amené de preuves empiriques au postulat de la théorie de l'« incentive salience » qui soutient que l'intensité de la motivation à obtenir une récompense est déclenchée par la perception d’un SC qui peut être directement modulée par l'état physiologique de l’individu.

Des multiples explications pourraient être envisagées. D'abord, les deux catégories d'odeurs (cosmétique et alimentaire) ont permis de faire face au besoin de propreté de la même manière et ainsi, l'individu a pressé de façon identique pour les deux récompenses. La deuxième raison peut être liée à l'intensité du dégoût induit. En effet, nous avons fait l'hypothèse que les sujets ont été dégoûtés, mais pas assez pour exécuter un effort supplémentaire pour obtenir des odeurs cosmétiques par rapport à l'autre catégorie. En fait, un effet de dégoût général a été observé sur la tendance à exécuter la tâche. Probablement, le dégoût à faible intensité a provoqué seulement une démotivation générale induite par une augmentation des affectes négatifs et une diminution des affects positifs, avec la conséquence que les individus dégoûtés ont diminué plus rapidement l'effort à exécuter la tâche comparée aux contrôles. Cependant, l'intensité n'a pas été assez élevée pour induire un besoin de propreté.

Afin de vérifier ultérieurement la sensibilité du paradigme PIT, nous avons développé une dernière expérience dans laquelle nous avons manipulé l’état de satiété et investigué la différence dans la mesure de la composante motivationnelle pour des stimulations olfactives alimentaires et cosmétiques (non-alimentaires). Dans cette étude, nous avons utilisé une approche différente par rapport à la troisième expérience, car nous avons manipulé l’état physiologique au début de la tâche PIT avant les phases d’apprentissage afin d’augmenter la probabilité d’observer une différence. Les résultats ont montré une absence de différences statistiquement significatives entre le groupe faim et le group satiété dans la phase Pavlovienne de conditionnement. Cela, nous a donc empêché de tester l’effet Transfer en fonction du groupe. Nous avons, par conséquence, analysé les données sur l’ensemble des participants sans tenir en considération l’état physiologique des individus. Les résultats ont montré que les participants mobilisés plus d’effort pour obtenir les images associées en précédence avec des récompenses par rapport aux images qui n’ont pas été précédemment associées avec des récompenses.

Le travail développé dans cette thèse présente plusieurs limites qui ouvrent sur de nouvelles perspectives indiquant où de nouveaux efforts devront être effectués dans le futur (voir chapitre 4.3). En particulier, l’absence d’un transfert spécifique pour les stimuli olfactifs cosmétiques dans un état
de dégoût (expérience 3) et l’absence d’un conditionnement Pavlovian pour les stimuli olfactifs alimentaires dans un état de faim (expérience 4) peut être due à des raisons méthodologiques. En premier lieu, nous avons opérationnalisé la composante motivationnelle en tant que nombre des pressions et en tant que force plutôt que en tant que choix de réponse associée à des touches du clavier. Nous avons fait l’hypothèse que l’effet spécifique était plus subtil de ce que l’on s’attendait et que le choix d’utiliser un capteur de force n’a pas permis de mettre en évidence cette différence subtile au niveau de la composante motivationnelle comme cela a été le cas pour Lovibond et al. (2015) qui ont utilisé des taux de réponse. Cependant, des recherches ultérieures doivent être faites afin de comparer les deux formes de réponse.

En deuxième lieu, nous avons supposé que la consommation directe des récompenses olfactives dans la phase de conditionnement Pavlovien, instrumental et la première partie de la phase initiale du transfert ont diminué la volonté subjective à obtenir des stimuli olfactifs, parce que le besoin personnel était déjà satisfait. Des recherches plus approfondies devraient dans le futur comparer les différences dans l’effort mobilisé en reproduisant le même design, mais en utilisant des points ou des images symboliques de récompenses olfactives pendant la phase de conditionnement Pavlovien instrumental et de test par rapport aux vrai récompenses olfactives. D’autres limites ont été présentées dans la thèse (voir chapitre 4.3).

Pour conclure, dans la partie théorique, nous avons présenté la variable parasite consistant en l’agréabilité anticipée comme potentiel problème qui provoquait les erreurs d’opérationnalisation de la composante hédonique et motivationnelle. Nous avons exploré s’il existait une corrélation entre ce concept et celui de motivation implicite et nous avons montré une absence de corrélation dans l’ensemble des études suggèrent donc que ces deux concepts sont uniques et séparés.

Conclusion

Un nombre croissant d’études rapporte l’utilité de mesurer d’autres indicateurs pour différencier deux produits ayant un niveau de plaisir semblable (King & Meiselman, 2010; King et al., 2013; Laros & Steenkamp, 2005; Ng et al., 2013a; Porcherot et al., 2010; Warrenburg, 2005). Cette thèse a testé la potentialité de la méthode PIT à mesurer la motivation implicite pour une récompense olfactive par rapport à une deuxième. Les résultats ont montré les limites du paradigme PIT à mesurer la différence de motivation pour deux stimuli olfactifs ayant des propriétés « récompensâtes » semblables. Le paradigme PIT peut être utilisé pour mesurer la motivation implicite pour une récompense olfactive ou pour deux récompenses olfactives ayant des propriétés « récompensâtes » très différentes. Cependant, les résultats montrent une impossibilité de l’outil à mesurer des différences motivationnelles pour des stimuli olfactifs ayant des propriétés « récompensâtes » très semblables. Nous avons donc conclu que le paradigme PIT n’était pas plus sensitive et n’amenait pas des
informations additionnelles comparé à la méthode hédonique classique utilisée couramment en industrie.