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Measuring wanting without asking: The Pavlovian-to-instrumental transfer paradigm under test

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ABSTRACT

In consumer science, measuring liking is posited to be the best method to understand preferences and food choice behaviour. Consumer research shows that highly rewarding products are more often bought than slightly rewarding products. However, detecting clear differences in preferences for similarly rewarding products, which have just launched on the market, is not always easy to investigate with liking measures. Consequently, finding other methods measuring preferences for similarly rewarding products is necessary. A well-established theoretical framework used to study reward processing, the incentive salience theory, argues that the pursuit of a positive outcome depends on three distinct components: the motivation to obtain it (*wanting*), the pleasure felt during its consumption (*liking*), as well as its automatic associations and cognitive representations (*learning)*. The Pavlovian-to-Instrumental Transfer (PIT) paradigm is a promising method used to investigate wanting in animals and humans. The human PIT task has been used in the chemosensory field in the presence of a single odour. In the present methodological studies, we further investigated the sensitivity of the PIT task to measure cue-triggered wanting by comparing two olfactory rewards. The first study used two olfactory stimuli with very different liking levels, whereas the second used two olfactory stimuli with similar liking levels. The results suggested that the PIT task was sensitive enough to detect the effort participants mobilized (wanting) to obtain two olfactory stimuli with very different liking levels, which was not the case for olfactory stimuli with similar liking levels. Implications of the PIT task for consumer research were discussed.

1. Introduction

In daily practices in consumer science, liking measurements constitute the principal method to investigate preferences that may ultimately be linked with choice behaviours. This is mainly based on the fact that rewarding products with high subjective liking scores are more often chosen compared to rewarding products with low liking scores (De Graaf et al., 2005; Kamen, 1962; Peryam & Pilgrim, 1957; Pilgrim, 1961; Pilgrim & Kamen, 1963; Schutz & Pilgrim, 1957). However, this relation becomes less obvious when choices concern similarly rewarding products launched on the market (De Graaf et al., 2005). Clear differences in preferences are in this case often difficult to detect with liking scales. There is thus a need to find new measures that could eventually more finely characterize the rewarding properties of products and understand consumer behaviour and choice. New methods to be applied in consumer science may be inspired from fundamental research on reward processing. A suitable theoretical framework could be the Incentive Salience Theory (IST, Berridge, 2007, 2009, 2012; Berridge & Robinson, 1998, 2003) which argues that the pursuit of a reward (e.g., a desired product) 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 three components involved in reward processing are usually positively correlated (e.g., you want what you like and you learned it from previous experiences). 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;

Abbreviations: IST, incentive salience theory; CS+, reinforced conditioned stimulus; CS−, non-reinforced conditioned stimulus; PIT, Pavlovian-to-instrumental transfer; VAS, visual analogue scale

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Robinson & Berridge, 1993). A crucial aspect of the IST is that it differentiates between explicit and implicit aspects of liking, wanting and learning (Berridge, Ho, Richard, & DiFeliceantonio, 2010), a differentiation generally not addressed in consumer studies.

The explicit facets of these components are: liking, wanting, and learning (without quotation marks) and are also referred to as the common terms pleasure, motivation, and cognitive learning, respectively.

In consumer studies, these components are measured using visual analogue scales and questionnaires (Andersen, Brockhoff, & Hyldig, 2019; Concas et al., 2019; Nacef et al., 2019; Ramsey et al., 2018; Muñoz-Vilches, van Trijp, & Piqueras-Fiszman, 2019). Furthermore, other scales are also used such as the Fawcett-Clark Pleasure Scale (FCPS; Fawcett, Clark, Scheftner, & Gibbons, 1983), the Snaith-Hamilton Pleasure Scale (SHAPS; Snaith et al., 1995), the Michigan Wanting and Liking Questionnaire (MWLQ; Berridge et al., 2010) and the Sensitivity To Reinforcement of Addictive & other Primary Rewards questionnaire (STRAP-R; Goldstein et al., 2010).

The main risks involved in using explicit methods are related to the participants and experimenters' misunderstanding of the wanting and liking terms. First, individuals that are not familiar with the wanting and liking terminology can easily say that what they like is also what they want, without making a difference between the two terms, and consequently, they do not answer in the manner that is expected by the experimenter. Second, the subjects could tend to give answers that will be viewed favourably by the researcher without giving their real preferences and motivations (social desirability bias, Edwards, 1953). Third, the inconsistency in interpreting the explicit facets of motivation and hedonic impact of the reward could be an additional issue in their correct operationalization. This is mainly due to the several definitions presented in the literature. More precisely, from the first to the last definition of the reward components, Berridge and his co-authors published several articles where these theoretical definitions evolved. These modifications, which are based on over more than 30 years of empirical research, increase our knowledge of reward processing, however, they also increase the confusion as to which definitions can be used to operationalize them. For instance, liking in the IST is defined as an experience of pleasure, so in this case the measurement should be done during or immediately after reward consumption. However, researchers in some studies (Born et al., 2011; Bushman, Moeller, Konrath, & Crocker, 2012) 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, without presenting the reward to be consumed. This kind of operationalization is not in line with the IST, because it measures the memory of liking and not the experience itself. The same operationalization is also sometimes used to measure explicit wanting (Leyton et al., 2002). According to Pool et al.'s systematic review (2016), an additional issue that may influence the inconsistency in the operationalization of liking and wanting is the underlying conceptual confounds in expected pleasantness. It is an evaluation of how good or how bad a specific reward is going to be and it does not correspond to any of the explicit facets of the wanting or liking components. In their systematic review, the authors reported that in 84 studies, 25% of them measured expected pleasantness to reflect liking and 13% to reflect wanting. However, expected pleasantness does not conceptually correspond to liking or wanting and consequently, the scientific community's use of this definition to measure liking and wanting provokes confusion in the correct meaning of these terms (see Pool, Sennwald, Delplanque, Brosch, & Sander, 2016 for a review on this topic).

The IST also define implicit facets of the different components of reward processing which are "liking", "wanting" and "learning" with quotation marks. "Liking" refers to a hedonic reaction that is not accompanied by conscious pleasure. "Wanting" 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). Finally, "learning" refers to the Pavlovian and instrumental learning associations from past hedonic experiences (Anselme & Robinson, 2016, Berridge, 1996, Kringelbach & Berridge, 2011).

In addition to the explicit methods, researchers proposed different ways to measure the implicit facets of motivation and hedonic impact.

"Liking" may be 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). "Wanting" is measured through conditioned approaches, incentive key force grip tasks, and effort expenditure for reward tasks. Finally, another less costly and demanding way to assess "liking" and "wanting" is by using implicit tests (Tibboel et al., 2011; Tibboel, De Houwer, & Van Bockstaele, 2015) such as 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). The main advantage of implicit measures compared to explicit measures is that the former might capture mechanisms that are not introspectively accessible, therefore, they are less consciously controlled and less susceptible to extraneous factors (e.g. social desirability, deception).

Although researchers found significant results using the AAT, SRC, AST and IAT methodologies, other scientists questioned the validity of these methods (Eder and Rothermund, 2008; Krieglmeyer, De Houwer, & Deutsch, 2013; Tibboel et al., 2015; Wiers, Van Woerden, Smulders, & De Jong, 2002 for a review). For instance, the IAT suffers from a critical drawback: the label choices. The labels *"I want"* and *"I do not want"* comprise hedonic content implying that the implicit association tested is at best, a mix between "liking" and "wanting". Moreover, in some wanting-IATs, the authors claimed to measure the "wanting" concept, but often measured instead the psychological concept of arousal (Wiers et al., 2002). In other liking-IATs, 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 only be related to a hedonic experience (Tibboel et al., 2015) and consequently, the generic terms of *"positive"* and *"negative"* are not appropriate to measure the concept of "liking" defined by the IST.

This non-exhaustive presentation of the different methods used to measure the explicit and implicit facets of the reward's components, highlights the current difficulty in measuring how much consumers are motivated to obtain a product. In order to overcome the issue of the measurement of the consumer's motivation in the IST framework, 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. A very important characteristic of this paradigm is that "wanting" is measured outside the consummatory phase. Therefore, it gives researchers the opportunity to assess "wanting" independently of the presence of the reward. The task is divided into three phases: instrumental, Pavlovian, and transfer test. The instrumental phase consists of an 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 the 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

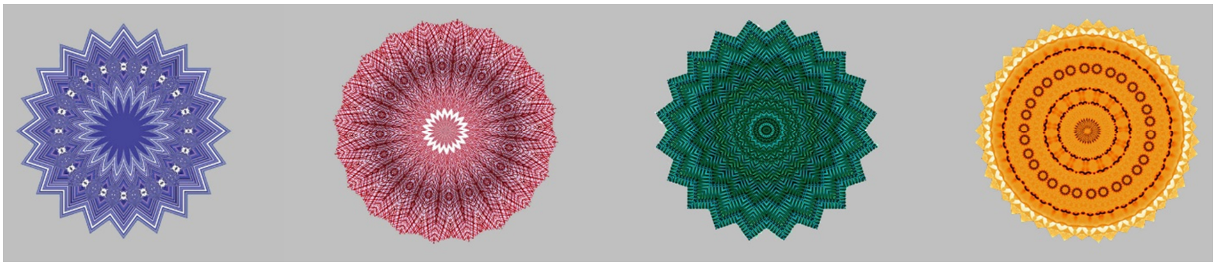

Fig. 1. The four abstract images used during the experiment. The first image was used during the instrumental training, reminder and partial extinction of the transfer test. The second, third and fourth images during the Pavlovian and the extinction phase of the transfer test.

caused by the presence of the reward. If the PIT effect takes place, the CS+ presentation induces an increase in action energization after its exhibition. At the end of the experiment, this measure is taken to reflect cue-induced "wanting". In the chemosensory field, an example of a successful PIT study comes from Pool, Brosch, Delplanque, and Sander (2015). In this experiment, only one pleasant odour (i.e., chocolate odour) was used and compared to a flow of air (no stimulus) during a stress and a 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 pressure test to induce physiological stress. During the extinction phase of the transfer test, participants were instructed to perform the task they learned in the instrumental phase and to squeeze the handgrip to obtain the reward in response to the images. Results showed that the PIT paradigm was sensitive enough to measure the effort mobilized ("wanting") to obtain the chocolate reward compared to no stimulus. Moreover, under stress, "wanting" and liking were dissociated, with stressed individual working more than stress-free participants to obtain a reward that was no longer necessarily liked (Pool et al., 2015; see also Sennwald, Pool, & Sander, 2017).

Although the PIT paradigm is a very promising tool to use in consumer research to compare one stimulus versus no stimulus, to our knowledge, it is still unclear the extent to which the PIT paradigm can be used to measure "wanting" when multiple olfactory stimuli are simultaneously used. In the present work, we aimed to test the sensitivity of the PIT paradigm to measure "wanting" when two olfactory stimuli with highly or slightly different liking levels were simultaneously used as well as to provide evidence supporting a potential application of the PIT paradigm in consumer science. Indeed, the current challenge in consumer research is to differentiate products that may often be very similarly liked and the PIT procedure could be a valuable asset to overcome this issue.

We conducted two experiments to investigate the sensitivity of the PIT task. In the first experiment, we used stimuli with markedly different rewarding properties (measured as the liking level, one stimulus really liked, the other one moderately liked). 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 from the same category (food odours) that slightly differed in their rewarding properties (measured as the liking level). We thought it could be worth testing and reporting whether this method would be able to differentiate levels of motivation to obtain two odours that slightly differed in liking. This objective was challenging because the two odours could have a similar basic drive and potentially lead to similar "wanting" levels, however, it is valuable information for the consumer science community for which the description of methodologies to differentiate similarly liked product is of particular interest.

2. Experiment 1

2.1. Goal

The aim of this experiment was to investigate whether the PIT procedure was a sensitive tool to differentiate "wanting" between olfactory stimuli that highly differed in liking levels. 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.

2.2. Material and methods

2.2.1. Material

2.2.1.1. Participants. Sixty-one undergraduate psychology students (10 men) participated for course credits. The study was approved by the 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.

2.2.1.2. 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 (Fig. 1).

2.2.1.3. Olfactory stimuli. In order to select the odours for the PIT experiments, we ran a test where 30 individuals (M = 28.6, SD = 5.66) evaluated a sample of 25 odours 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"). We selected nine odours from the initial set of 25 odours (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. These nine odours were used in the PIT paradigm with a different pool of participants.

2.2.1.4. Instrumental apparatus. An isometric handgrip dynamometer (TSD121C, Biopac Systems, Santa Barbara, CA) 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) and recorded (sampling rate 30 Hz) with MATLAB (version 8.0). The variation in compression of the TDS121C isometric dynamometer resulted in a differential voltage signal that was linearly proportional to the force exerted by the participants. The participants received visual online feedback concerning the force they

Table 1
The odours used for the first experiment with the mean of pleasantness, intensity, familiarity and edibility.

Odours	Concentration (ml/l)	Dipropylene glycol (ml/l)	Mean Pleasantness (SD)	Mean Intensity (SD)	Mean Familiarity (SD)	Mean Edibility (SD)
Peach NP	5.00	5.00	7.32 (± 2.47)	6.59 (± 1.91)	5.93 (± 2.60)	4.07 (± 2.55)
Linalol	5.00	5.00	7.01 (± 2.28)	5.80 (± 1.98)	4.93 (± 2.79)	2.07 (± 1.27)
Tutti Frutti	2.00	8.00	8.36 (± 2.13)	6.49 (± 1.59)	8.40 (± 1.59)	6.93 (± 2.37)
Geraniol	5.00	5.00	4.79 (± 2.10)	5.58 (± 2.52)	5.80 (± 2.96)	2.93 (± 2.49)
Galbex	5.00	5.00	4.92 (± 2.93)	6.29 (± 2.22)	6.46 (± 2.90)	4.13 (± 3.39)
Pipol	2.00	8.00	4.78 (± 2.81)	6.36 (± 2.37)	6.07 (± 3.51)	2.60 (± 2.26)
Green tea	5.00	5.00	7.52 (± 2.96)	6.54 (± 2.18)	4.86 (± 3.25)	2.73 (± 2.46)
Pin ABS	5.00	5.00	7.01 (± 1.97)	6.44 (± 6.52)	4.69 (± 3.12)	2.77 (± 2.28)
Aladinate	5.00	5.00	5.21 (± 2.35)	6.60 (± 1.96)	4.86 (± 2.72)	2.60 (± 2.10)
Empty	–	10	–	–	–	–

Note. The odours were provided by Firmenich, SA, Geneva, Switzerland. The essences were dissolved in propylene glycol. We pre-selected nine odours with the similar level of intensity (between 5.58 and 6.60). On the pleasantness scale, we pre-selected four mildly pleasant ones varying between 4.78 and 5.21 and five very pleasant varying between 7.01 and 8.36. One test tub was filled in only with propylene glycol as control condition.

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).

2.2.2. Methods

The experiment was divided into two main phases: an odour evaluation and a PIT testing phase (divided into three sub-phases: instrumental, Pavlovian, and transfer phases; Table 2).

2.2.2.1. Odour evaluation task. Before beginning the experiment, participants completed a consent form and a questionnaire on demographic information. 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.

2.2.2.2. 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 4–12 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 (Fig. 2). 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

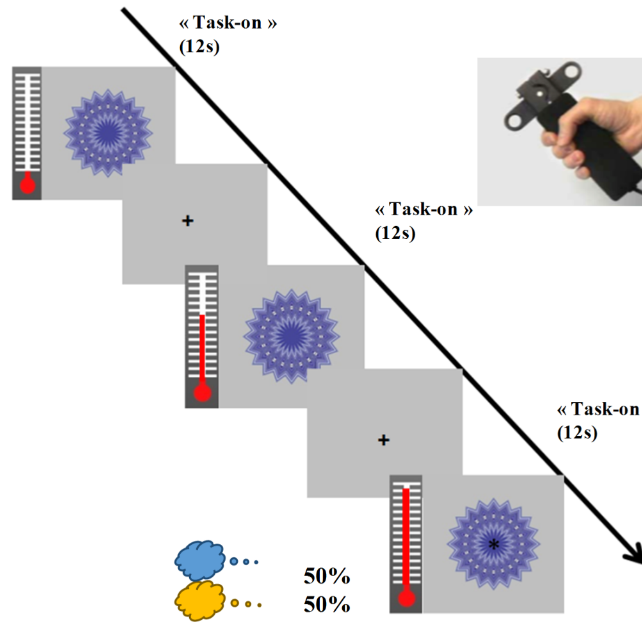

Fig. 2. Instrumental conditioning. During the instrumental conditioning, participants learned to squeeze a handgrip to trigger the release of an odour. Fifty percent of the time the odour released was the mildly rewarding odour and fifty percent of the time was the mostly rewarding odour.

Table 2
The experimental design of the first experiment.

Instructions	Questionnaire	Odour evaluation	Instrumental	Pavlovian	PIT
Participation agreement, demographic information questionnaire	TEPS questionnaire	VAS of 10 odours. Selection of the mildly and mostly rewarding odours	Instrumental training (24 trials)	Pavlovian conditioning (36 trials)	Transfer test (18 trials)
7 min	5 min	5 min	12 min	16 min	15 min

Note. First participants filled in the consent form, the questionnaire on demographic information and the TEPS. Second, participants performed an odour evaluation test on a computer screen. Two odours (mildly and mostly 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 min. In the figure, the time is given for each part of the experiment.

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 applied. 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.

2.2.2.3. Analogous 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 second 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 (Fig. 3). 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. 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.

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).

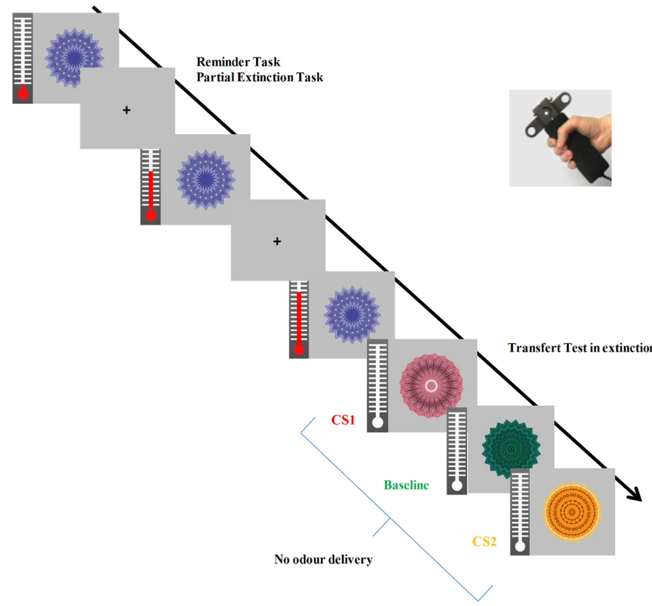

Fig. 4. Transfer test. Before the extinction phase, the subject performed a reminder followed by a partial extinction phase. During the entire transfer test, the subjects were told to squeeze the handgrip if they wished to do so as learned in the instrumental conditioning training. CS1 corresponded to 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.

2.2.2.4. 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 (Fig. 4). 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

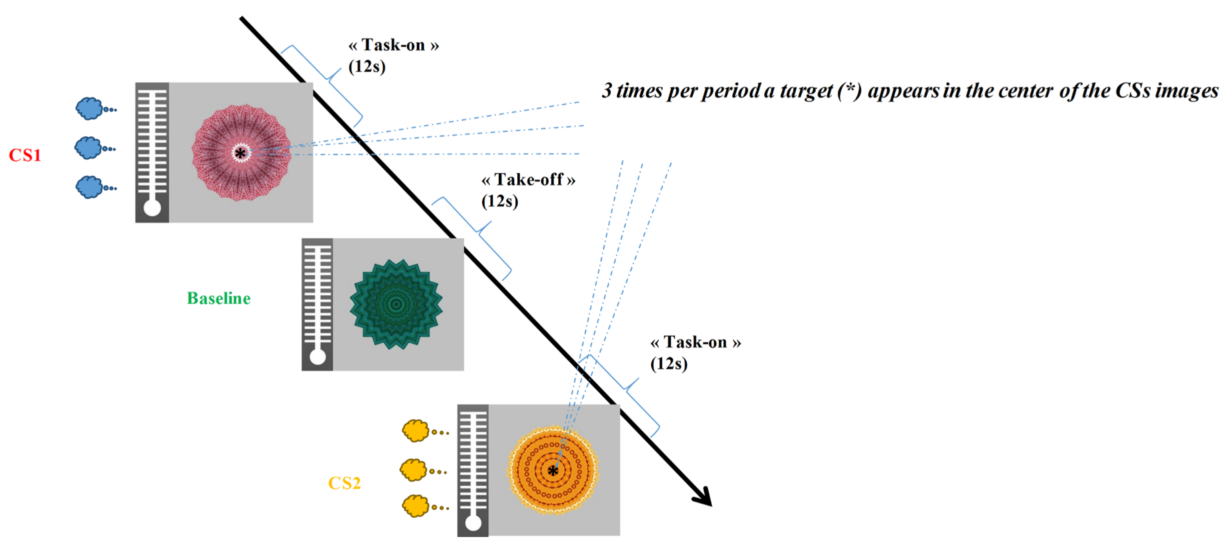

Fig. 3. Analogous Pavlovian conditioning. During the analogous Pavlovian conditioning, participants were exposed to repeat pairings of the most positive conditioned stimulus (CS1) associated to the mostly rewarding odour and the less positive conditioned stimulus (CS2) associated to the mildly rewarding 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 (task-on phase). When the baseline was displayed at the screen, no target or odour appeared (task-off phase).

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.

2.2.2.5. Strength measures. First, to minimize force variability between participants, the signal was standardized by subtracting the minimal voltage value from each voltage point recorded every 33 ms and dividing this value by the difference between the maximum voltage minus the minimum voltage. Then, 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. This first parameter was a squeeze frequency measure already used in the literature (Talmi, Seymour, Dayan, & Dolan, 2008; Pool et al., 2015). The second indicator measured the global force exerted by each participant during the task. This indicator was more implicit compared to the first one, because the participants were unaware of the amount of strength they were exerting, and they could not easily consciously control their force. The total force was obtained by integrating the standardized signal using the trapezoidal numerical integration of Matlab to compute the area of the signal. The results were expressed in standardized values (without unit) over a period of 12 s.

2.3. 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 mostly 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, two for the second criteria, three for the third criteria, and three for the fourth criteria. In addition, four subjects were excluded for technical problems with the handgrip recording, leaving 45 subjects for the statistical analysis.

2.3.1. Odour evaluation

Paired *t* tests revealed that the mean pleasantness rating of the mostly rewarding odours ($M = 85.10$, $SD = 7.80$) was statistically higher than that of the mildly rewarding odour ($M = 52.11$, $SD = 3.7$, $t(44) = 25.31$, $p \leq 0.001$, $d = 5.41$; Fig. 5a). The mean intensity of the mostly rewarding odours ($M = 72.58$, $SD = 10.73$) was statistically higher than that of the mildly rewarding odour ($M = 61.12$, $SD = 15.60$, $t(44) = 4.78$, $p \leq 0.001$, $d = 0.84$; Fig. 5b).

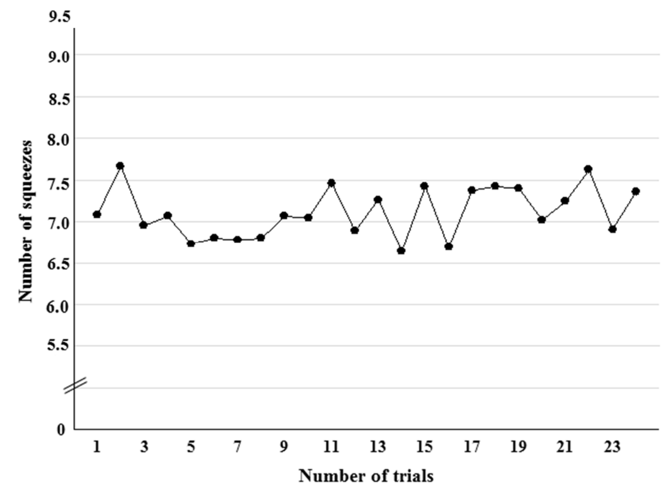

Fig. 6. Averaged number of squeezes as a function of the trial.

2.3.2. 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 [$F(23, 1012) = 0.72$, $p = .83$, $\eta^2 = 0.016$], suggesting that from the beginning of the task, participants pressed sufficiently and constantly to perform the task after a short training phase (Fig. 6).

2.3.3. Analogous Pavlovian conditioning

Successful Pavlovian contingency learning was assessed using the likability test of the CSs and the reaction times of the key-pressing task.

2.3.3.1. Likability rating indicator. A repeated-measures ANOVA applied to the likability ratings of the three Pavlovian images (CS1, CS2, baseline) revealed a significant effect of image [$F(2, 88) = 14.41$, $p \leq .001$, $\eta^2 = 0.25$; Fig. 7a]; post hoc analysis showed that participants liked CS1 more ($M = 67.83$, $SD = 15.13$) than they liked CS2 [$M = 43.9$, $SD = 21.8$, $t(44) = 4.98$, $p \leq 0.001$, $d = 1.28$] and more than they liked the baseline [$M = 53.5$, $SD = 19.0$, $t(44) = 3.84$, $p \leq 0.001$, $d = 0.83$]. A trend was found between the baseline and CS2 [$t(44) = 1.98$, $p = .052$, $d = 0.45$], revealing that participants tended to like less the CS2 than the baseline.

2.3.3.2. RT indicator. For the key-pressing task, we analysed RTs on the

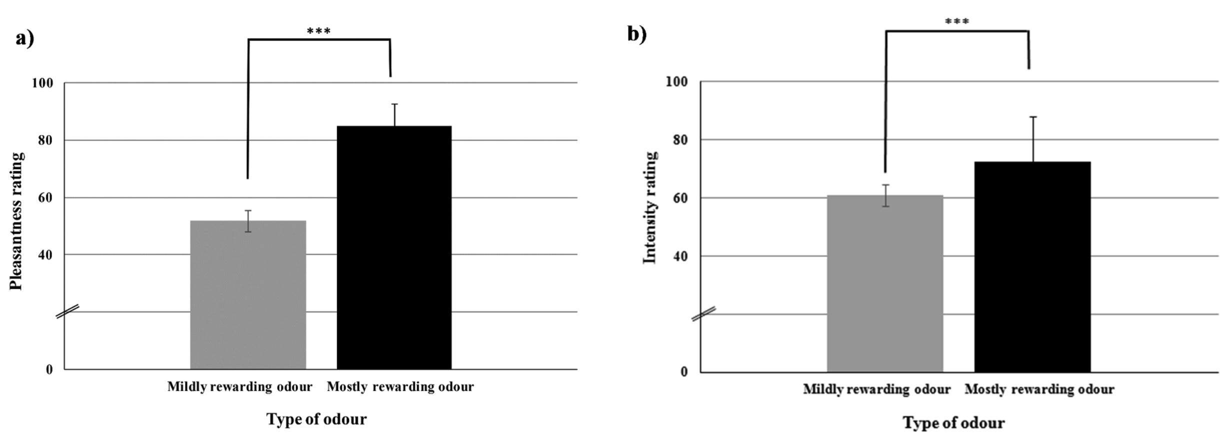

Fig. 5. a) Averaged pleasantness scores for the mildly rewarding odours and the mostly rewarding odours ($N = 45$). Error bars represented SEM. ***$p \leq 0.001$. b) Averaged intensity scores for the mildly rewarding odour and the mostly rewarding odour ($N = 45$). Error bars represent SEM. ***$p \leq 0.001$.

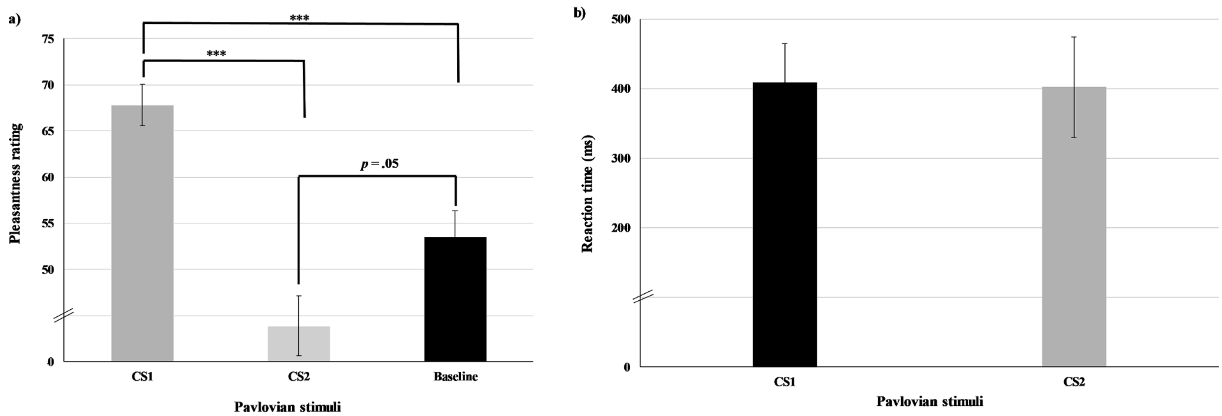

Fig. 7. a) Averaged pleasantness ratings for the 3 pictures after the Pavlovian conditioning. Error bars represented SEM. $^{***}p \leq 0.001$. b) Averaged reaction times (ms) to detect the cue during the presentation of the mostly positive conditioned stimulus (CS1) and of the mildly conditioned stimulus (CS2). Error bars represented SEM.

first target of the task-on period (Fig. 7b). The results showed that during the first trial, CS1 ($M = 408.28$, $SD = 56.22$) did not produce statistically significant smaller RTs among participants than did CS2 [$M = 401.95$, $SD = 72.38$, $t(44) = 0.75$, $p = .46$, $d = 0.10$].

2.3.4. Transfer test

Effort mobilization was assessed at a trial level by calculating two indicators:

1. Number of peaks exceeding 50% of the participant's maximal force
2. Total force: The total exerted force reflected the energy investment during the entire 12 s of measurement. The total force on each block for each repetition and each Pavlovian stimulus was recorded, with a total of 18 trials for each participant.

2.3.4.1. Number of peaks exceeding 50% of the participant's maximal force. From previous research (Pool et al., 2015; Talmi et al., 2008), we calculated the number of squeezes exceeding 50% of the participant's maximal force to evaluate the effort mobilized to obtain a reward. A 2 (block: 1, 2) × 3 (image: CS1, CS2, baseline) × 3 (repetition: 1, 2, 3) repeated-measures ANOVA showed a tendency toward interaction between block and image [$F(2, 88) = 2.38$, $p = .09$, $\eta^2 = 0.05$]. Post hoc analysis on the first block showed that the number of squeezes tended to be higher for CS1 ($M = 10.10$, $SD = 1.82$) than for CS2 [$M = 8.34$, $SD = 1.79$, $t(45) = 1.86$, $p = .07$, $d = 0.98$]. This tendency became statistically significant in the second block where the number of peaks was statistically higher for CS1 ($M = 10.31$, $SD = 1.92$) than for CS2 [$M = 8.12$, $SD = 1.74$, $t(44) = 2.20$, $p = .03$, $d = 1.20$]. No statistically significant difference was found between CS1 ($M = 10.10$, $SD = 1.82$) and the baseline ($M = 9.97$, $SD = 1.81$) in the first block [$t(44) = 0.12$, $p = .90$, $d = 0.07$] or in the second block between CS1 ($M = 10.31$, $SD = 1.92$) and the baseline [$M = 8.84$, $SD = 1.83$, $t(44) = 1.23$, $p = .22$, $d = 0.78$]. No statistically significant difference was found in the first block between the baseline and CS2 [$t(44) = -1.44$, $p = .157$, $d = -0.9$] or in the second block [$t(44) = -0.73$, $p = .47$, $d = 0.40$]. A difference between block 1 and block 2 was observed for the baseline [$t(44) = 2.30$, $p = .03$, $d = 0.62$], revealing a decrease in the number of squeezes. No statistically significant difference between block 1 and block 2 was found for CS1 [$t(44) = -0.42$, $p = .68$, $d = 0.12$] or for CS2 [$t(44) = 0.57$, $p = .57$, $d = 0.12$], revealing a constant effort for CS stimuli (Fig. 8).

2.3.4.2. Total force. A 2 (block: 1, 2) × 3 (image: CS1, CS2, baseline) × 3 (repetition: 1, 2, 3) repeated-measures ANOVA showed a significant effect of block [$F(1, 44) = 8.56$, $p = .0054$, $\eta^2 = 0.16$] and

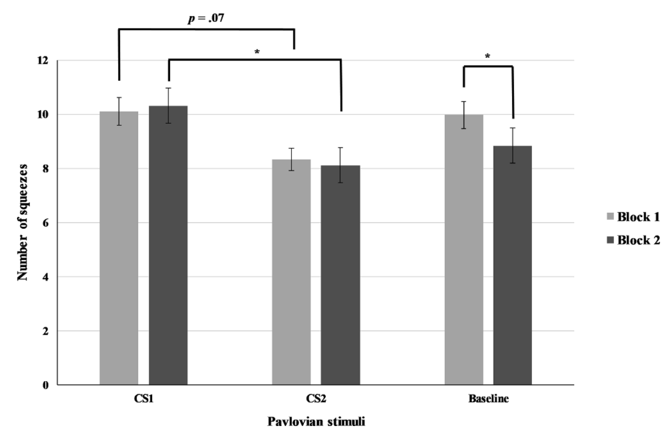

Fig. 8. Number of squeezes exceeding 50% of the maximal force of the participant during the extinction phase of the transfer test as a function of Pavlovian stimuli and the block's number. Error bars represent SEM. $^{*}p \leq 0.05$.

repetition [$F(2, 88) = 8.28$, $p \leq 0.001$, $\eta^2 = 0.16$] and a two-way interaction between block and image [$F(2, 88) = 4.099$, $p = .02$, $\eta^2 = 0.09$]. The block effect showed a statistically significant decrease in the total amount of force from the first to the second block (Fig. 9a). 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 [$M = 75.94$, $SD = 11.09$, $t(44) = 3.51$, $p \leq 0.001$, $d = 0.91$] and from the first to the third repetition [$M = 75.46$, $SD = 12.66$, $t(44) = 2.82$, $p \leq 0.01$, $d = 0.89$]. No statistically significant difference was found between the second and the third repetition [$t(44) = 0.27$, $p = .790$, $d = 0.04$; Fig. 9b].

The statistically significant interaction between block and image revealed differences in the total force exerted in the two blocks depending on each Pavlovian stimulus. The only Pavlovian stimulus in which the exerted force did not decrease from the first to the second block was CS1. More precisely, in the first block, the strength exerted by the participants when CS1 ($M = 80.74$, $SD = 9.33$) was presented on the screen did not statistically decrease compared with the tension exerted for CS1 [$M = 75.01$, $SD = 9.34$, $t(44) = 1.32$, $p = .20$, $d = 0.61$] 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 [$M = 71.44$, $SD = 10.66$, $t(44) = 3.42$, $p \leq 0.001$, $d = 1.80$]. The exerted force in the first block for CS2 ($M = 82.38$, $SD = 14.17$) tended to

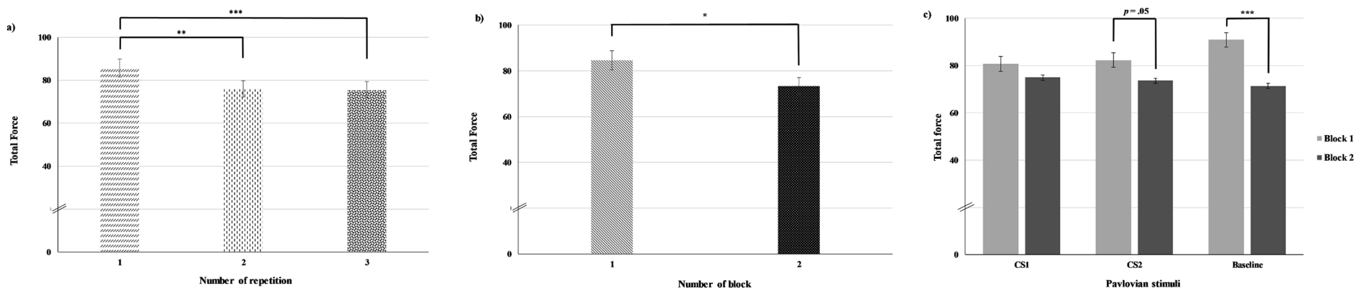

Fig. 9. a) Total amount of force during the extinction phase of the transfer test as a function of the block's number. Error bars represented SEM. $^{*}p \leq 0.05$. b) Total force exerted during each repetition of the extinction phase of the transfer test as a function of the repetition's number. Error bars represented SEM. $^{***}p \leq 0.001$ and $^{**}p \leq 0.01$. c) Total exerted force during each block of the extinction phase of the transfer test for each 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. $^{***}p \leq 0.001$.

decrease in the second block for CS2 [$M = 73.69$, $SD = 11.72$, $t(44) = -2.00$, $p = .052$, $d = 0.67$]. The reduction in the force exerted on the handgrip when CS2 or the baseline appeared on the screen revealed a decline in the motivation to obtain these stimuli. There was no statistically significant difference in force in the first block between CS1 and CS2 [$t(44) = -0.25$, $p = .80$, $d = 0.14$] or in the second block [$t(44) = -0.18$, $p = .85$, $d = 0.13$; Fig. 9c].

2.4. Discussion of Experiment 1

The aim of this first experiment was to investigate the sensitivity of the PIT to measure cue-induced "wanting" for two odours with highly different liking levels. Our prediction was that "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 operationalisations 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 with.

Concerning the transfer test, the two indicators of "wanting" revealed a higher motivation to obtain CS1 compared to 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 particular, 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: 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 (Cartoni et al., 2016).

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.

Based on this first 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 differed only slightly in their liking levels.

3. Experiment 2

3.1. Goal

The aim of Experiment 2 was to investigate whether the PIT procedure was a sensitive tool to differentiate the "wanting" between olfactory stimuli that differ slightly in liking levels. Two odours with slight differences in liking levels were used: strawberry and tutti-frutti (bubble gum fragrance). We predicted that participants would mobilize a higher effort to obtain the first mostly rewarding odour (UCS1) than they would to obtain the second rewarding odour (UCS2) in the transfer test.

3.2. Material and methods

3.2.1. Material

3.2.1.1. Participants. Fifty-four subjects (11 men) participated in the study, which was approved by the ethical committee of the University of Geneva. Healthy adults between 18 and 39 years old ($M_{age} = 23.8$, $SD_{age} = 5.21$) were recruited from an online announcement on social networks. They have normal or corrected-to-normal vision, no repeated olfactory problems, no smoking habits, and no history of psychiatric or neurological diseases. 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 performed in French and English.

3.2.1.2. Visual stimuli and instrumental apparatus. The neutral images, instrumental apparatus, and procedure for delivery of the olfactory stimulation were the same as for Experiment 1 (see "Methods and Materials" section in Experiment 1).

Table 3
The strawberry and tutti-frutti means of pleasantness, intensity, familiarity and edibility.

Odours	Concentration (ml/l)	Dipropylene glycol (ml/l)	Mean Pleasantness (SD)	Mean Intensity (SD)	Mean Familiarity (SD)	Mean Edibility (SD)
Strawberry	2.00	8.00	7.91 (± 2.14)	6.84 (± 1.63)	8.06 (± 2.02)	6.80 (± 2.54)
Tutti Frutti	5.00	5.00	8.15 (± 2.13)	6.49 (± 1.60)	8.40 (± 1.59)	6.93(± 2.37)
Empty	–	10	–	–	–	–

Note. The odours were provided by Firmenich, SA, Geneva, Switzerland. The essences were dissolved in propylene glycol. The two odours had similar level of pleasantness, intensity, familiarity and edibility. One test tub was filled in only with propylene glycol as control condition.

3.2.1.3. Odours. Two odours (strawberry and tutti-frutti) provided by Firmenich SA were selected from an initial set of 25 odours. In a preliminary test, the strawberry and the tutti-frutti fragrances were evaluated on the VAS by 16 participants ($M = 28.2$, $SD = 3.78$) as having non-significantly different levels of pleasantness [$t(15) = 0.77$, $p = .50$, $d = 0.25$], intensity [$t(15) = 0.81$, $p = .40$, $d = 0.22$], familiarity [$t(15) = 0.55$, $p = .60$, $d = 0.19$], and edibility [$t(15) = 0.13$, $p = .90$, $d = 0.05$, see Table 3].

We used these two odours in our PIT paradigm. For each participant, the odour with the highest liking level was defined as the US1 and the other one as the US2. Consequently, the USs could be different from one participant to another.

3.2.2. Methods

3.2.2.1. Methodological adaptation. In the first experiment, we noticed that individuals understood from the first trial of instrumental conditioning how to correctly press the power grip (see Fig. 6). Consequently, 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 consumer tests.

The procedure was similar to the one described in Experiment 1 (see Table 4). Participants were asked to fill in a consent form and a demographic information questionnaire. They then rated the strawberry and tutti-frutti odours on a pleasantness, intensity, familiarity, and edibility scale (i.e., odour evaluation test). Later, they performed the PIT procedure with the very pleasant odours having slight differences in liking levels (strawberry and tutti-frutti).

3.3. Results

We applied the same criteria as used in Experiment 1 to include or exclude participants from the statistical analysis. No participant was excluded.

3.3.1. Odour evaluation

Even if very close, paired *t* tests revealed that the mean of the second rewarding odour ($M = 69.06$, $SD = 12.49$) was statistically lower than that of the first mostly rewarding odour [$M = 72.70$, $SD = 14.43$, $t(53) = 3.57$, $p \leq 0.001$, $d = 0.27$; Fig. 10a]. The intensity of the second rewarding odour ($M = 52.49$, $SD = 26.79$) was statistically lower than that of the first mostly rewarding odour ($M = 73.12$, $SD = 15.55$ [$t(53) = 4.73$, $p \leq 0.001$, $d = 0.94$; Fig. 10b].

3.3.2. Instrumental conditioning

We calculated the number of squeezes exceeding 50% of the participant's maximal force in order to assess the effort mobilized to obtain a reward (Pool et al., 2015; Talmi et al., 2008). A repeated-measures ANOVA performed on the four trials did not show a trial effect [$F(3,159) = 1.23$, $p = .30$, $\eta^2 = 0.02$], revealing that from the beginning, the participants pressed sufficiently to perform the task after a short training phase (Fig. 11).

3.3.3. Analogous Pavlovian conditioning

Successful Pavlovian contingency learning was assessed using the likability of the CSs and the RTs on the key-pressing task.

3.3.3.1. Likability 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 ANOVA applied to the likability ratings of the three Pavlovian images (CS1, CS2, and baseline) revealed a significant effect of image [$F(2, 106) = 6.98$, ≤ 0.01, $\eta^2 = 0.12$]. Post hoc analysis showed that the subjects liked CS1 more ($M = 61.9$, $SD = 2.15$) than they liked the baseline [$M = 51.7$, $SD = 3.01$, $t(53) = -2.84$, $p \leq 0.01$, $d = -3.90$]. They also liked CS2 more ($M = 64.7$, $SD = 2.16$) than they liked the baseline [$t(53) = -3.18$, $p \leq 0.01$, $d = -4.96$]. There was no statistical difference between CS1 and CS2 [$t(53) = -0.86$, $p = .39$, $d = 1.29$] so we could not demonstrate that participants like the CS image previously associated with the first mostly rewarding odour more than they liked the CS image previously associated with the second rewarding odour (Fig. 12a).

3.3.3.2. RT indicator. During the first target of the task-on period of the key-pressing task, the RTs for CS1 ($M = 414.04$, $SD = 51.55$) tended to be higher than those for CS2 [$M = 400.01$, $SD = 57.43$, $t(53) = 1.94$, $p = .06$, $d = 0.26$; Fig. 12b].

3.3.4. Transfer test

As in Experiment 1, two indicators were developed to measure "wanting" during the extinction phase of the transfer test: number of peaks exceeding 50% of the participant's maximal force and total force.

3.3.4.1. Number of peaks exceeding 50% of the participant's maximal force. We calculated the number of squeezes exceeding 50% of the 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) × 3 (image: CS1, CS2, baseline) × 3 (repetition: 1, 2, 3) repeated-measures ANOVA showed an effect of repetition [$F(2, 106) = 4.11$, $p \leq 0.01$, $\eta^2 = 07$]. The number of peaks was stable from the first ($M = 11.52$, $SD = 1.93$) to the second repetition [$M = 11.57$, $SD = 2.03$, $t(53) = -0.18$, $p = .85$, $d = 0.03$]. It then started to decline from the second to the third repetition [$M = 10.83$, $SD = 1.94$, $t(53) = 2.87$, $p = .0059$, $d = 0.37$, Fig. 13]. A main difference was found between the first and third repetition [$t(53) = 2.08$, $p \leq 0.05$, $d = 0.36$]. No effect was found for image [$F(2, 106) = 0.38$, $p = .69$, $\eta^2 = 0.007$], indicating no statistically significant difference in the total number of squeezes exerted when CS1, CS2, and the baseline were on the screen. In addition, no statistically significant difference was found between CS1 in block 1 ($M = 11.64$, $SD = 1.41$) and CS1 in block 2 [$M = 11.40$, $SD = 1.57$, $t(53) = 0.50$, $p = .61$, $d = 0.16$], between CS2 in block 1 ($M = 11.39$, $SD = 1.45$) and CS2 in block 2 [$M = 10.90$, $SD = 1.51$, $t(53) = 0.76$, $p = .45$, $d = 0.33$], or between the baseline in block 1 ($M = 11.57$, $SD = 1.52$) and the baseline in block 2 [$M = 10.95$, $SD = 1.52$, $t(53) = 1.51$, $p = .14$, $d = 0.41$].

3.3.4.2. Total force. A 2 (block: 1, 2) × 3 (image: CS1, CS2, baseline) × 3 (repetition: 1, 2, 3) repeated-measures ANOVA showed a statistically significant effect of block [$F(1, 53) = 19{,}0$, $p \leq 0.001$, $\eta^2 = 0.26$] and of repetition [$F(2, 106) = 4{,}27$, $p = .02$, $\eta^2 = 0.07$].

Table 4
The experimental design of the second study.

Instructions	Questionnaire	Odour evaluation	Instrumental	Pavlovian	PIT
Participation agreement, demographic information questionnaire	TEPS questionnaire	Evaluation of the 2 odours on 3 characteristics: intensity, pleasantness and familiarity	Instrumental training (4 trials)	Pavlovian conditioning (36 trials)	Transfer test (18 trials)
7 min	5 min	2 min	5 min	16 min	15 min

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 min. In the figure, the time is given for each part of the experiment.

The block's effect showed that the total amount of force decreased significantly from the first to the second block (Fig. 14a).

The repetition's effect showed that the force exerted on the handgrip decreased significantly from the first to the third repetition (Fig. 14b). More precisely, post hoc analysis showed a difference in the force from the first ($M = 90.91$, $SD = 9.70$) to the third repetition [$M = 85.50$, $SD = 10.97$, $t(53) = 2.81$, $p \leq 0.01$, $d = 0.49$]. No statistically significant difference was observed between the first and the second ($M = 88.50$, $SD = 9.89$) repetition [$t(53) = 1.33$, $p = .19$, $d = 0.25$] or between the second and the third repetition [$t(53) = 1.67$, $p = .10$, $d = 0.26$].

No statistically significant difference was found in the total force between the three Pavlovian stimuli [$F(2,106) = 1.12$, $p = .33$, $\eta^2 = 0.02$]. However, a difference between CS1 in block 1 ($M = 93.63$, $SD = 7.53$) and CS1 in block 2 ($M = 88.15$, $SD = 8.61$) was found [$t(53) = 2.04$, $p \leq 0.05$, $d = 0.68$], revealing a decrease in the total force exerted when CS1 was shown on the screen in block 2 (Fig. 14c). 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 [$M = 83.15$, $SD = 8.14$, $t(53) = 2.84$, $p \leq 0.01$, $d = 0.28$], indicating a decline in the force for this stimulus as well. A statistically significant difference was observed between the force exerted for the baseline in the first block ($M = 91.25$, $SD = 8.54$) and that exerted for the baseline in the second block [$M = 80.80$, $SD = 8.06$, $t(53) = 3.89$, $p \leq 0.001$, $d = 1.26$], also indicating a decline in the force for this stimulus.

3.4. Discussion of Experiment 2

The aim of second experiment was to investigate whether differences in "wanting" may still be observed for odours that slightly differ in liking levels.

From the descriptive and statistical analyses of the instrumental learning phase, 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 with.

Concerning the transfer phase, 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.

4. General discussion

The present experiments were developed with the ultimate objective to find a method that could measure an individual's motivation to obtain one product when two products were compared. A key procedure used to explore "wanting" component in animals and humans is the PIT. This procedure helps to investigate reward processing in the laboratory by studying "wanting" outside of consummatory pleasure. The validity of this PIT procedure to differentiate the "wanting" associated with a rewarded stimulus (CS+) from that associated with a non-rewarded stimulus (CS−) in a chemosensory setting was previously demonstrated (Pool et al., 2015). In this article, we wanted to investigate the sensitivity of the PIT paradigm to measure "wanting" when two olfactory stimuli with highly (experiment 1) or slightly (experiment 2) different liking levels were simultaneously used.

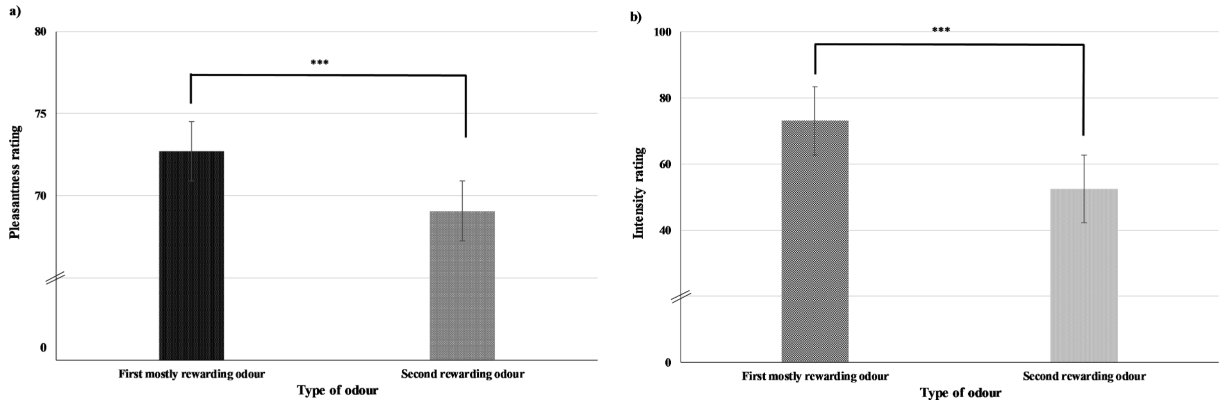

Fig. 10. a) Averaged pleasantness scores of the first mostly rewarding odour and the second rewarding odours ($N = 54$). Error bars represented SEM. $^{***}p \leq 0.001$. b) Averaged intensity scores of the first mostly rewarding odour and the second rewarding odours ($N = 54$). Error bars represented SEM. $^{***}p \leq 0.001$.

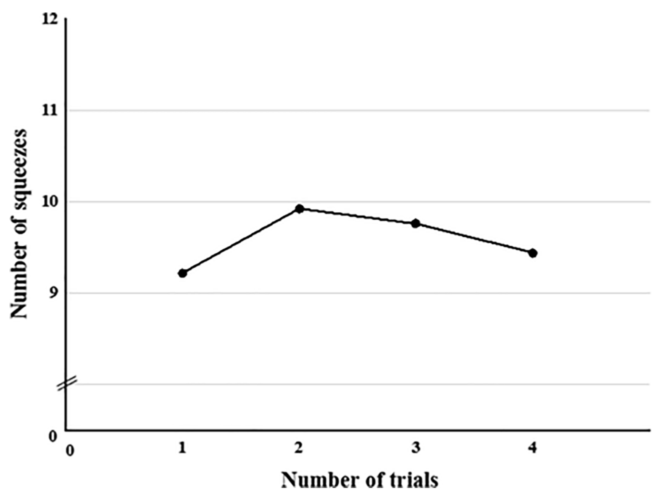

Fig. 11. Averaged number of times participants ($N = 54$) squeezed the handgrip as a function of trials. Error bars represented SEM.

In both experiments, we measured the effort mobilized using the same instrumental tool with two indicators: a handgrip, allowing us to measure the effort mobilized through the measurement of the number of peaks and the force exerted.

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 about

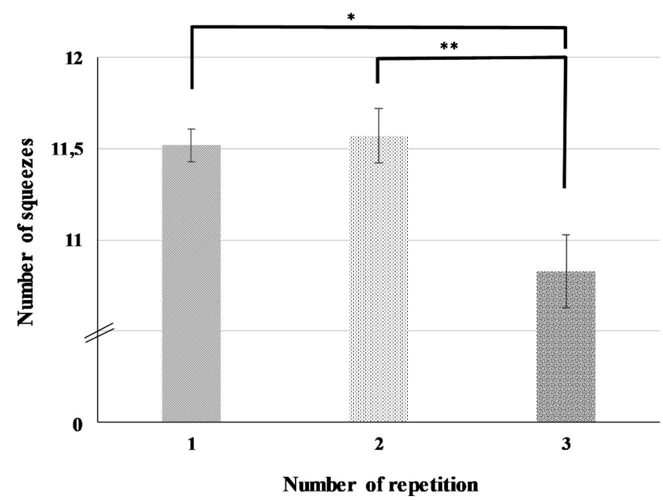

Fig. 13. Number of squeezes exceeding 50% of the maximal force of the participants during each repetition of the extinction phase of the transfer test. Y-axis corresponded to number of squeezes and x-axis to number of repetition (1, 2, 3). Error bars represented SEM. $^{**}p \leq 0.01$ and $^{*}p \leq 0.05$.

21 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

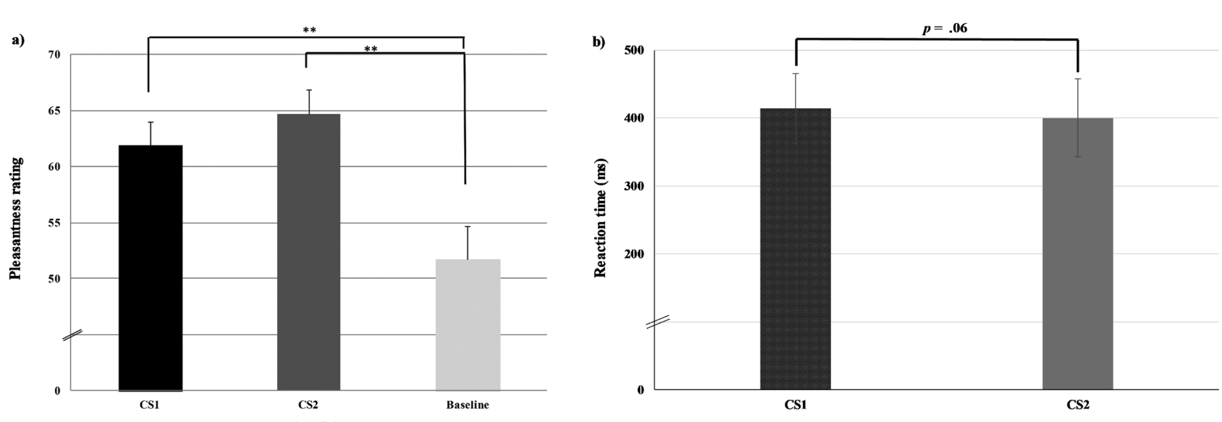

Fig. 12. a) Averaged pleasantness ratings for the 3 Pavlovian Stimuli after the Pavlovian conditioning. Error bars represented SEM. $^{**}p \leq 0.01$. b) Averaged reaction times to detect the cue during the presentation of the first mostly positive conditioned stimulus (CS1) and the second positive conditioned stimulus (CS2). Error bars represented SEM.

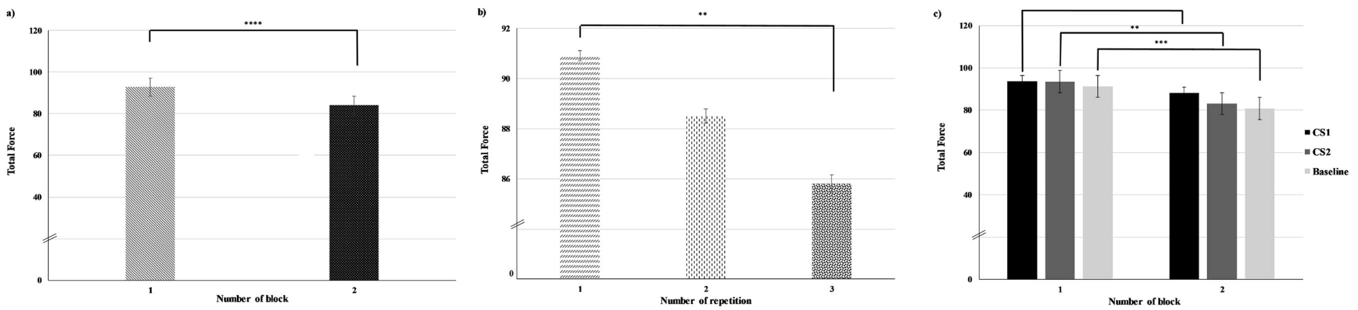

Fig. 14. a) Averaged of the total amount of force (integral) calculated during the extinction phase of the transfer test. Error bars represented SEM. $^{****}p \leq 0.001$. b) Total force exerted during each repetition of the extinction phase of the transfer test. Error bars represented SEM. $^{**}p \leq 0.01$. c) Total force exerted for Pavlovian stimuli in the two blocks. Error bars represented SEM. $^{*}p \leq 0.05$, $^{**}p \leq 0.01$ and $^{***}p \leq 0.001$.

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 only 5 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. The first alternative is that we did not find a difference in the effort mobilized for CS1 and CS2, because PIT was not sensitive enough to discriminate "wanting" for odours 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. In the second alternative, we can assume that there was no true difference in the amount of effort mobilized to obtain CS1 and CS2, because the two odours were from the same category (food odours). We knew that comparing two odours from the same category was a challenge because they could have a similar basic drive and potentially no difference in the "wanting" measure could be observed. However, we wanted to investigate whether the PIT paradigm could be useful in consumer research where this issue is relevant. Our final assumption was 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 similar.

In summary, the PIT procedure was able to dissociate "wanting" for olfactory stimuli that were highly different in liking levels. However, when two slightly different olfactory pleasant odours from the same family are compared, the PIT test may not provide additional information compared to a liking measure.

It would be valuable to test the 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 such an experiment. Finally, another important point to consider is the effort to mobilize asked to the participants in a task. Moreover, 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 such as the effort asked that should be carefully controlled. 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 provided the same information. 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. Further studies should be performed to investigate the added values of using the force indicator when multiple olfactory stimuli are used in consumer sciences.

5. 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. In consumer sciences, this procedure represents an alternative to reliably assess the "wanting" for different products while controlling for classical biases encountered with questionnaires or when "wanting" is assessed during reward consumption. Though the PIT provides an unbiased measure of "wanting", its exact sensitivity to different kind of rewards or products remains to be further established.

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